MASSACHUSETTS WATER RESOURCES AUTHORITY

WATER SYSTEM MASTER PLAN

SEPTEMBER 2013

2013 MWRA Water System Master Plan

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2013 MWRA Water and Wastewater Master Plan - Executive Summary

OVERVIEW

Since its inception, MWRA has expended $7.7 billion on capital initiatives (FY86 through FY13). Of this spending, 73 percent has supported wastewater system improvements, 25 percent water system improvements, and two percent for business and operations support. The 2013 Master Plan documents the investment needs of MWRA's regional water and wastewater systems over the next 40 years (FY14-53) through the identification of 367 prioritized projects estimated at $4.0 billion in 2013 dollars. All projects are either already programmed in the FY14 Capital Improvement Program (CIP) (total of $2.0 billion) or are recommended for consideration in future CIPs (total of $2.0 billion). Development of the Master Plan is a collaborative process involving MWRA's Planning, Operations, Engineering, and Finance staff. The 2013 Master Plan is a comprehensive update of the 2006 Master Plan.

The Master Plan is an important tool for annual capital planning and budgeting and its spending recommendations have been incorporated in MWRA's multi-year financial planning estimates. The draft 2013 Master Plan was used as a reference to help guide development of the CIP spending cap for FY14-18. The final 2013 Master Plan has been updated to be consistent with the final FY14 CIP budget and is intended to be a companion document to facilitate staff and Advisory Board recommendations and allow for comparison of future investment needs between different parts of the water and wastewater systems. The Master Plan provides information on water and wastewater system facilities and operations at a level of detail to provide the reader the context to understand recommended future capital spending. The 2013 Master Plan lists both projects programmed in the CIP and projects recommended for future consideration during the 40-year planning period. The focus is on projects proposed to require capital spending during the next two 5-year CIP cap cycles, FY14-18 and FY19-23. Following these two 5-year periods, potential capital needs during additional 10-year (FY24-33) and 20-year (FY34-53) planning periods are projected. Estimates of project costs and schedules over the shorter term are expected to be more reliable than out-year estimates. The Master Plan is a key reference document that will be updated every five years to reflect changing water and wastewater system needs, updated asset conditions, evolving regulatory requirements, revised priorities identified through new studies, and other appropriate considerations.

The MWRA Master Plan has two volumes, one detailing water system needs and the second detailing wastewater system needs. This comprehensive Executive Summary covers both volumes and summarizes overall costs. The Water System Master Plan includes major chapters on treatment, the transmission system, and the metropolitan system. The Wastewater System Master Plan includes distinct chapters for major facilities (e.g., Deer Island Treatment Plant, Residuals Pellet Plant, remote headworks, sewers, pump stations, etc.). Chapters include project recommendations to address the issues and needs identified during the planning process. Both Water and Wastewater Plans also provide related background information including system goals and objectives, history of the system, and the assumptions which provide the context for master planning, including: regulatory framework, future population estimates, water demand and quality, wastewater flow and quality, residuals volumes, etc.

In June 2013, the Board of Directors set the FY14-18 5-year CIP spending cap at $791.7 million. The FY14-18 CIP cap is $348.0 million (31 percent) less than the $1,139.2 million average of the prior two five-year CIP cap periods. Staff expect the Board will continue to establish CIP spending caps for future 5-year periods (FY19-23 and beyond) as part of future CIP process discussions. Total Master Plan water and wastewater needs identified for FY14-18 are approximately $720 million, including $675 million in projects currently programmed in the CIP and $45 million in new projects recommended for consideration in future CIPs. Total water and wastewater needs identified for FY19-23 are approximately $1,218 million, including $1,039 million in projects currently programmed in the CIP and $179 million in new projects recommended for consideration in future CIPs. MWRA's estimated water and wastewater reinvestment needs for the 40 year planning period are presented in Table 1 and also displayed graphically in Figures 1, 2, and 3.

All wastewater and water project costs recommended in the Master Plan are summarized by chapter in Attachments A and B. Projects representing about $3.0 billion are rehabilitation or replacement of existing infrastructure assets at end of their useful life.

The vulnerability assessments undertaken in response to the events of September 11, 2001; along with redundancy and security upgrades, current and anticipated regulatory requirements, water quality, and energy management considerations help shape the Master Plan. Some of the major themes include:

- For the Water System
  - Redundancy for transmission, distribution, and storage;
  - Water pipeline rehabilitation;
  - Increased funding for asset protection needs; and,
  - Continued financial assistance to support member community projects.

- For the Wastewater System
  - Continued asset protection needs at Deer Island;
  - Timing of residuals facilities replacement needs and co-digestion pilot;
  - Timing of remote headworks design/construction upgrades;
  - Timing of interceptor renewal/asset protection projects;
  - Ramping down of CSO Control Plan expenditures and planning for CSO control performance assessment; and,
  - Continued financial assistance to support member community projects.

Issues being debated nationally that could impact MWRA, such as more stringent federal and state regulation, a higher level of CSO control, storm surge/climate change, and pharmaceuticals in wastewater, are identified in the Master Plan, but there are no project-specific recommendations or significant costs included.

TABLE 1
2013 MWRA MASTER PLAN PROJECT COST SUMMARY ($ in millions)

Asset	FY14-18	FY19-23	FY24-33	FY34-53	SUBTOTAL FY14-53
Water Treatment and Land Acquisition Programmed in FY14 CIP	$31,101	$79	$0	$0	$31,180
Future Recommended - Water Treatment and Land Acquisition	$0	$12,500	$29,000	$47,000	$88,500
Transmission System and Dams Programmed in FY14 CIP	$74,135	$233,502	$118,738	$0	$426,375
Future Recommended - Transmission System and Dams	$0	$6,100	$31,725	$54,000	$91,825
Metropolitan System, Lab, SCADA, Metering, Energy and Info Management Programmed in FY14 CIP	$200,676	$304,887	$99,674	$9,906	$615,143
Future Recommended - Metropolitan System, Lab, SCADA, Metering, Energy and Info Management	$5,370	$20,830	$118,700	$80,000	$224,900
SUBTOTAL - Water Projects Programmed in FY14 CIP	$305,912	$538,468	$218,412	$9,906	$1,072,698
SUBTOTAL - Future Recommended - Water Projects	$5,370	$39,430	$179,425	$181,000	$405,225
TOTAL WATER PROJECTS	**$311,282**	**$577,898**	**$397,837**	**$190,906**	**$1,477,923**
Wastewater Treatment and Residuals Programmed in FY14 CIP	$200,687	$323,510	$50,428	$0	$574,625
Future Recommended - Wastewater Treatment and Residuals	$29,345	$22,800	$211,750	$535,000	$798,895
Headworks, Tunnels, Pump Stations, CSO Facilities and CSO Control Plan Programmed in FY14 CIP	$137,943	$122,176	$63	$0	$260,182
Future Recommended - Headworks, Tunnels, Pump Stations, CSO Facilities and CSO Control Plan	$3,000	$86,500	$81,000	$228,000	$398,500
Sewers, SCADA, Metering and Community Financial Assistance Programmed in FY14 CIP	$30,480	$54,521	$23,817	$0	$108,818
Future Recommended - Sewers, SCADA, Metering and Community Financial Assistance	$7,400	$30,240	$174,000	$181,240	$392,880
SUBTOTAL - Wastewater Projects Programmed in FY14 CIP	$369,110	$500,207	$74,308	$0	$943,625
SUBTOTAL - Future Recommended - Wastewater Projects	$39,745	$139,540	$466,750	$944,240	$1,590,275
TOTAL WASTEWATER PROJECTS	**$408,855**	**$639,747**	**$541,058**	**$944,240**	**$2,533,900**
Total Projects Programmed in FY14 CIP	$675,022	$1,038,675	$292,720	$9,906	$2,016,323
Total Future Recommended Projects	$45,115	$178,970	$646,175	$1,125,240	$1,995,500
TOTAL PROJECTS	$720,137	$1,217,645	$938,895	$1,135,146	$4,011,823

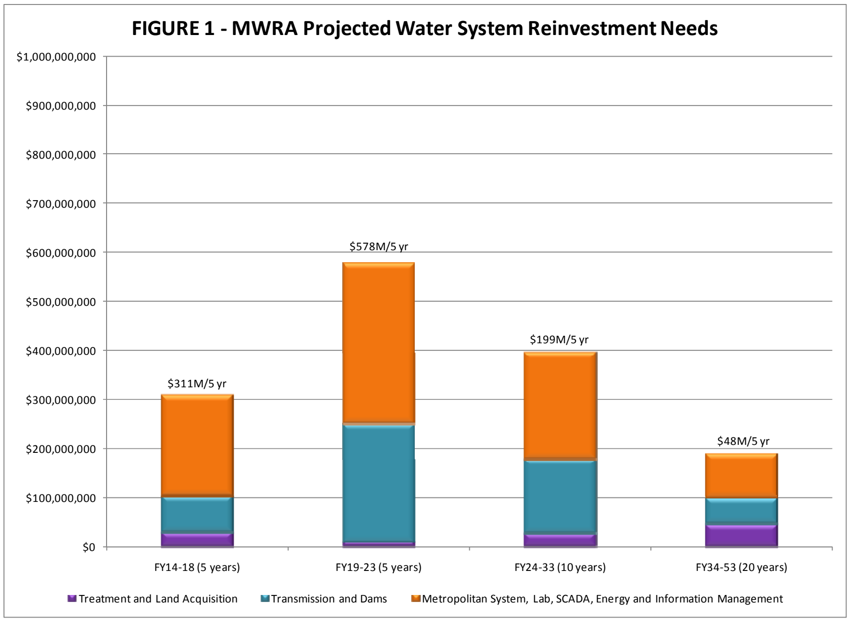


FIGURE 1 - MWRA Projected Water System Reinvestment Needs
$1,000,000,000
$900,000,000
$800,000,000
$700,000,000
$600,000,000
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$0
$311M/5 yr
$578M/5 yr
$199M/5 yr
$48M/5 yr
FY14-18 (5 years)
FY19-23 (5 years)
FY24-33 (10 years)
FY34-53 (20 years)
Treatment and Land Acquisition
Transmission and Dams
Metropolitan System, Lab, SCADA, Energy and Information Management

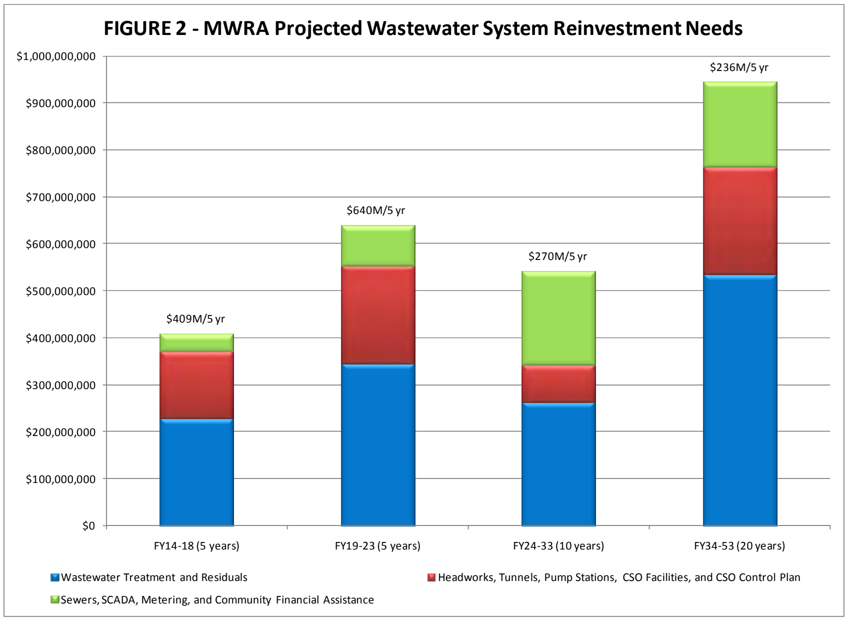


FIGURE 2 - MWRA Projected Wastewater System Reinvestment Needs
$1,000,000,000
$900,000,000
$800,000,000
$700,000,000
$600,000,000
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$0
$409M/5 yr
$640M/5 yr
$270M/5 yr
$236M/5 yr
FY14-18 (5 years)
FY19-23 (5 years)
FY24-33 (10 years)
FY34-53 (20 years)
Wastewater Treatment and Residuals
Headworks, Tunnels, Pump Stations, CSO Facilities, and CSO Control Plan
Sewers, SCADA, Metering, and Community Financial Assistance

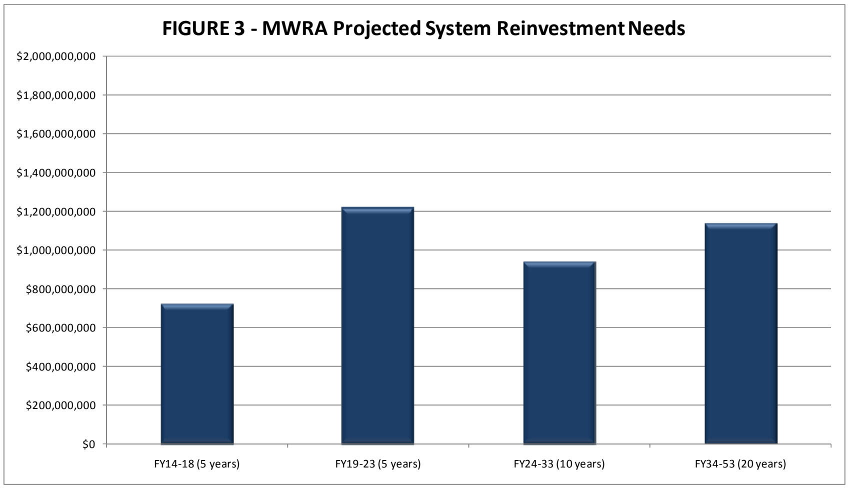


FIGURE 3 - MWRA Projected System Reinvestment Needs
$2,000,000,000
$1,800,000,000
$1,600,000,000
$1,400,000,000
$1,200,000,000
$1,000,000,000
$800,000,000
$600,000,000
$400,000,000
$200,000,000
$0
FY14-18 (5 years)
FY19-23 (5 years)
FY24-33 (10 years)
FY34-53 (20 years)

All Master Plan projects have been prioritized on a scale from 1 to 5, as follows: 1 – critical; 2 – essential; 3 – necessary, 4 – important, and 5 – desirable. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will improve system reliability and maintain effluent/residuals quality. Lower priority projects will optimize system performance, assure future capacity, and provide more efficient operation. Project ratings were assigned by MWRA senior managers in concert with Operations, Engineering, and Planning staff. Project priority is reviewed during the annual CIP development process.

The MIS Five Year Information Technology Strategic Plan (IT Plan) addressing MWRA's technological and system needs was completed in 2012. The IT Plan recommendations have now been incorporated into the FY14 CIP and are focused on four major areas of improvement: Application Improvement Programs; Information Security Program; Information Technology Management Programs; and, Information Technology Infrastructure Programs. Each of these focus areas is further broken into specific subprograms. Overall, the FY14 CIP contains approximately $20.9 million dollars to support these efforts with approximately $19.3 scheduled to be spent within the FY14-18 time period. The major areas of focus are: replacing aging systems and the network architecture, improving disaster recovery, enhancing data integration, consolidating server/computing resources, and implementing applicable best practices as part of software vendor solutions. The goal is to continue to support efficient administrative, financial, operational, engineering and planning functions with cost-effective technology. To the extent that some of these improvements are more directly focused on water and wastewater operations, they are discussed in both Master Plan documents. However, although costs are noted, they are not carried in the Water and Wastewater System Master Plan. Please refer to the IT Plan for more detailed information.

SUMMARY OF THE 2013 WATER SYSTEM MASTER PLAN

MWRA's water system includes its source reservoirs, treatment facilities, transmission lines, and distribution system facilities and pipelines; the system (excluding the source reservoirs) has an estimated replacement asset value of approximately $6.5 billion. There has been significant investment in MWRA's water system. The earlier $1.7 billion Integrated Water Supply Improvement Program which included watershed protection, construction of new water treatment, transmission and storage facilities, and relining or replacing of MWRA and community water pipes began to address deferred maintenance. SCADA technology has been adopted throughout the system, a rehabilitation program to complete the upgrading of pump stations is complete, and MWRA has rehabilitated miles of its distribution system pipeline and constructed new pipeline where redundancy or other system needs have been identified. Subsequent work is adding UV disinfection to the two treatment facilities; addressing remaining system redundancy needs and incorporating asset protection funding into annual planning.

Notwithstanding MWRA's success in carrying out this comprehensive infrastructure improvement effort, there remain system infrastructure challenges to be addressed. Total water system needs identified for the FY14-53 Master Plan timeframe are approximately $1.5 billion (in current dollars), including all projects currently in the CIP and those recommended for consideration in future CIPs. Approximately 56 percent of the total water system need addresses remaining system redundancy costs and approximately 37 percent is programmed for the rehabilitation or replacement of existing infrastructure assets at end of their useful life. The remaining 7 percent includes completion of the UV disinfection processes, energy management projects, watershed land acquisition and optimization of other water system assets.

Table 2 shows the breakdown by planning period.

TABLE 2 - 2013 Water System Master Plan Cost Summary

	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
Projects Programmed in the FY14 CIP	305,912	538,468	218,412	9,906	1,072,698
Projects Recommended for Future CIPs	5,370	39,430	179,425	181,000	405,225
Total	311,282	577,898	397,837	190,906	1,477,923

The water system needs assessment is based on the following major assumptions and findings:

- The 300 mgd safe yield of the MWRA water system is sufficient to meet future demand for water both within the service area and additional demand outside the service area.

- Modeling efforts indicate climate change is not expected to have significant impacts on reservoir yield, in fact, safe yield may increase slightly. Changes in climate may encourage surrounding communities to turn to MWRA for portions of their supply as droughts become more frequent or severe.

- No design and construction funds are included to address the impacts on the MWRA water system of potential changes in federal or state regulations.

- Water supply redundancy and new storage projects provide operational flexibility and enhance system security. Planning for redundancy for key elements of both the transmission and distribution systems was a focus of the 2006 Water System Master Plan. Specific projects to address these needs are now programmed in the CIP with major milestones completed by 2025 and the remaining implementation ongoing through FY37 (final phase of Southern Extra High work) and a total remaining cost of approximately $831 million. This includes design and construction of projects to address redundancy for the southern part of the service area served by the Metropolitan tunnel system and the rehabilitation/replacement of WASM 3 which will address redundancy for the northern part of the Metropolitan tunnel system.

- Master Plan recommendations include inspections of the Cosgrove Tunnel as well as the Metropolitan Tunnel System (Quabbin Tunnel Inspection is in the FY14 CIP and is scheduled to begin in FY19). The Master Plan proposes a placeholder value of $65 million for design and rehabilitation of the Metropolitan Tunnels. This is intended to address access, tunnel inspection and initial valve replacement needs; however, if inspections of any of the tunnels were to indicate more significant problems, costs could be much higher.

- The Master Plan again emphasizes the need to continue systematically lining the remaining MWRA-owned older unlined cast-iron mains (approximately 58 miles) to address potential water quality degradation concerns and related health risks in light of MWRA customer expectations and EPA's anticipated direction for distribution system regulation, and to continue to replace/rehabilitate more than 21 additional miles of steel pipes prone to corrosion and susceptible to leaks. Metropolitan system pipeline expenditures identified in the CIP or recommended in the Master Plan are approximately $271 million (excludes WASM 3 pipe miles and costs).

- The Master Plan recommends a pipeline study in FY20 to help MWRA assess the ongoing need for rehabilitation beyond the above work. The study will look at the any pipe remaining to be rehabilitated (mostly constructed since 1950), expected replacement cycles for lined pipes and assess information on corrosion and other factors.

- The Master Plan recommends continuing to systematically address the long-term need to protect and eventually replace other water system assets, including equipment, valves, pump stations, storage facilities, treatment and transmission system buildings and equipment (not including tunnels or piping), dams, and support systems, $272 million, FY14-53.

- Financial assistance to support member community water system rehabilitation projects to help maintain high quality water is planned to continue but must be evaluated against competing MWRA CIP needs. Even with the substantial progress made over the last 15 years via MWRA's community water loans, about 2,100 miles (33 percent) of community-owned water mains remain unlined. The Master Plan recommends two additional water loan program phases FY21-40 (each at $210 million in loans over 10 years) to extend the current program approved through FY20. Since there is no grant component to water financial assistance, the impact to MWRA's CIP is minor compared to the sewer grant/loan program.

For the water system, this Master Plan varies somewhat significantly from the previous Master Plan. During that planning effort, the focus was on major shortcomings in overall system redundancy and the need to identify and move projects forward to address this issue. The CIP now incorporates much of this work. Master Plan findings and recommendations for water priority projects during the FY14-23 timeframe are summarized below. The Master Plan identifies $889 million in water system needs during this period (excluding community financial assistance). Of this $889 million, $844 million is in the existing CIP and $49 million is recommended for inclusion in future CIPs.

The Board of Directors has set a spending cap of $791.7 million for the FY14-18 time period. Work to establish the cap incorporated information from this Master Plan. All projects have been prioritized on a scale from 1 to 5, with 1 being projects considered critical and 5 considered desirable. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will fix existing reliability problems related to single points of failure, address facilities in poor condition where the ability to provide uninterrupted service or adequate flow is compromised, and meet basic hydraulic performance requirements, including adequate distribution storage. Lower priority projects will maintain infrastructure integrity and maintain efforts to manage system demands. Project ratings were assigned by MWRA senior managers in concert with Planning and Coordination Department staff. All MWRA projects (water, sewer, and business support) will be further prioritized during the CIP planning cycles.

The Transmission System – Tunnels and Aqueducts, Facilities, and Dams

MWRA's water transmission system consists of over 100 miles of tunnels and aqueducts in daily use which transport water by gravity from the supply reservoirs to points of distribution within the service area. The basic layout of the system as designed is fundamentally sound. System improvements over time have allowed for older facilities, no longer in daily use, to remain as critical emergency standby facilities as long as maintained and linked to new facilities where necessary. The performance standards for a major transmission system are: ability to transport sufficient water to meet the maximum daily demands of the service area, and reliability in that there must be sufficient redundant components to ensure a continued supply of water system if any one "leg" of the system were to fail. MWRA's transmission system ably meets system demands and much of the system has redundant components that may be brought on line.

However, as noted in the 2006 Master Plan and discussed in this plan, shortfalls in redundancy remain. This work has been added to the CIP since the last Master Plan. The critical project was to complete the Water Transmission Redundancy Plan (WTRP) which identified the major failure scenarios for the Metropolitan tunnel system and identified potential levels of service. This iterative process allowed MWRA to develop a range of alternatives to address these redundancy shortfalls. Preliminary projects to address redundancy of the Cosgrove Tunnel, the City Tunnel, the City Tunnel Extension and the Dorchester Tunnel were developed. The Wachusett Aqueduct Pump Station was determined to be the best alternative to address Cosgrove Tunnel redundancy and that project is currently in design. For the Metropolitan tunnel system, work is now ongoing to refine the concepts developed for the northern and southern portions of the Metropolitan system and move forward with environmental review and move into the design phases for each project.

The Master Plan process has also considered the needs of the many facilities that are part of the transmission system. Again, many projects have been added to the CIP since the completion of the 2006 Master Plan. This includes improvements to halt any ongoing deterioration and ensure safe and secure facility operations at some facilities and at other locations, more extensive modifications are proposed or underway to increase operational flexibility and to modernize equipment and systems.

MWRA, under its 2004 Memorandum of Agreement with the Department of Conservation and Recreation (DCR), is responsible for water supply dams, with a couple of exceptions. MWRA previously paid DCR Division of Watershed Management to perform capital improvements for these dams. Based on fall 2005 inspections, much work has been completed. Long-term, continued periodic maintenance of both the earthen and the masonry dams will be necessary.

In the near-term (through FY23), the Master Plan identifies approximately $313 million in transmission system project needs including projects currently in the FY14 CIP and new work proposed.

Treatment Plants

The FY14 CIP shows approximately $25 million to be spent for water treatment related costs and facility modifications during the FY14-18 time frame. This includes the remaining costs of completing the addition of UV disinfection at both the CWTP and at the Quabbin WTP. And it includes a new asset protection program at the CWTP for $500,000. The Master Plan recommends that an additional $53.5 million be allocated to asset protection for these facilities during the FY19-53 time period.

The Metropolitan System

The Metropolitan System consists of approximately 284 miles of distribution pipeline east of Shaft 5, eleven storage tanks, eleven pump stations, nine tunnel shafts, and approximately 4700 valves. The system is divided into 7 pressure zones.

As noted earlier, MWRA is proceeding to address important distribution system pipeline redundancy problems areas in the Northern Intermediate High (NIH), Southern Extra High (SEH), and the WASM 3 service areas and, more generally, in service areas with single spine mains. The NIH and SEH also have shortfalls in storage. An additional 20 mg of storage is also under construction for the Northern Low service area (Spot Pond Covered Storage). Significant redundancy and rehabilitation work was added to the CIP as a result of the previous Master Plan. The CIP currently contains almost $600 million in Metropolitan System projects in the FY14-53 timeframe with much of it prior to FY24. This includes the replacement/rehabilitation of WASM 3 which also provides redundancy to the City Tunnel and City Tunnel Extension as currently conceived. The distribution system network has approximately 79 remaining miles of unlined cast-iron pipe, posing water quality concerns, and 39 miles of steel pipe not yet rehabilitated which is prone to corrosion and susceptible to leaks; both are recommended for continued focus over the long-term, as are valve replacements. Some of this work is within the existing CIP and a number of pipelines are also addressed in the Master Plan. The Master Plan also recommends continued funding for pump station asset replacement as well as for asset replacement for covered storage facilities at appropriate intervals. SCADA components and continued water meter system upgrades need to addressed cyclically as well.

Land Acquisition

The FY14 CIP includes a total of $6 million to enable DCR to acquire parcels of, or interests in, real estate critical to protection of the watershed and source water quality. The Master Plan recommends an ongoing program of approximately $1 million per year through the FY19-53 planning horizon for an additional $35 million or a total of $41 million.

Community Financial Assistance – Local Water System Assistance Program

Even with the substantial progress made over the last 15 years, MWRA estimates that over 2,100 miles of community water main remain unlined, representing a future community water main replacement/rehabilitation cost of over $1.0 billion. For master planning purposes, staff recommend future third and fourth phases of the Local Water System Assistance Program be considered for funding in future CIPs. Each new phase is recommended to provide $210 million in interest-free loans (with 10-year loan repayments) during the FY21-30 and FY31-40 timeframes. MWRA staff will continue to work cooperatively with the Advisory Board to identify potential program improvements which may be recommended to the Board for approval.

SUMMARY OF THE 2013 WASTEWATER SYSTEM MASTER PLAN

MWRA's wastewater system is a complex network of conduits and facilities receiving flow from 43 member sewer communities covering an area of about 518 square miles. The regional system serves approximately 2.2 million people, including the City of Boston and surrounding metropolitan area. The Deer Island Treatment Plant (DITP) receives an average daily flow of 360 mgd and has a peak wet weather capacity of 1,270 mgd, with additional system capacity available at combined sewer overflow (CSO) outfalls. Residuals from DITP are processed into pellets for beneficial reuse at MWRA's sludge-to-fertilizer plant in Quincy. The MWRA collection system includes four remote headworks facilities, a network of 274 miles of sewer pipelines and cross-harbor tunnels, 13 pump stations, one screening facility, and six CSO treatment/storage facilities. MWRA also operates the Clinton Advanced Wastewater Treatment Plant (AWWTP) providing sewage treatment services to the Town of Clinton and the Lancaster Sewer District. MWRA's goal is to operate and maintain these facilities to provide uninterrupted wastewater collection and treatment service in a safe, cost-effective, and environmentally sound manner.

MWRA's wastewater infrastructure has an estimated replacement value of over $6.6 billion. The scale and scope of MWRA's wastewater system operation – encompassing collections, pumping, CSO, treatment, effluent discharge, and beneficial reuse of residuals – presents challenges in maintenance, rehabilitation, and replacement. Deer Island alone has 70,000 equipment and instrumentation components. Regular maintenance and replacement cycles have become standard plant operating practice, but will become increasingly costly as the plant ages. Capital projects across the system will be implemented while facilities are on-line, posing operational challenges, and project staffing considerations will also need to be weighed. Finally, all system spending is against the backdrop of rates management.

Total wastewater needs identified for the FY14-53 Master Plan timeframe are over $2.53 billion (in current dollars), including $0.94 billion already programmed in the FY14 CIP and $1.59 billion recommended for consideration in future CIPs. Over 94 percent, $2.40 billion of the $2.53 billion needs estimate for all wastewater projects, are rehabilitation or replacement of existing infrastructure assets at end of their useful life. The remaining $130 million in needs are for CSO Control Plan projects, treatment or interceptor projects to optimize the existing system or add capacity, wastewater modeling, new equipment that supports automated facility operation, technology upgrades, and studies/condition assessments.

The needs assessment is based on the following major assumptions and findings:

- No new communities are expected to join the wastewater system. Future population and employment growth in the service area is projected to be modest. Wastewater flow is not expected to increase and wastewater quality parameters are not projected to change.

- Storm surge together with anticipated sea level rise resulting from the changing climate will affect a number of MWRA coastal wastewater facilities. The Master Plan assumes any significant flood mitigation efforts will be undertaken as each facility is rehabilitated or upgraded, and that simpler measures will be implemented as maintenance efforts.

- No significant design and construction funds are included for potential long-term regulatory changes that may impact MWRA, beyond those items anticipated ($15 million for phosphorus removal and technology upgrades at Clinton) based on current NPDES permit discussions and the 2013 revised draft Clinton permit. Future regulatory issues that may have cost implications for MWRA include: more stringent limits on nutrients, conventional pollutants, or emerging contaminants; more stringent focus on reduction or elimination of sanitary sewer overflows (SSOs), expansion of MWRA's role in local stormwater permitting; a higher level of CSO control; or more stringent biosolids reuse criteria.

- Significant asset protection needs at Deer Island will continue (estimated at over $450 million for the next 10 years) and the residuals pellet plant facility will require large-scale equipment replacement (included in the FY14 CIP at $100 million over the next 10 years). MWRA is in development of a long-term residuals plan and will begin piloting co-digestion in FY14. Modest funds ($250,000) are currently included in the CIP for co-digestion upgrades. Based on the outcome of the pilot project, additional capital expenditures may be recommended to implement co-digestion long-term. Additional co-digestion funds are not yet included in the CIP or Master Plan, but a portion may be covered within the existing residuals equipment replacement budget.

- The cross-harbor tunnels are assumed to be in good condition. A $5 million tunnel inspection, condition assessment, and shaft repair project is programmed in the current CIP during FY19-23. The condition of the cross-harbor tunnels and potential need for future investment is a significant unknown for MWRA until the inspection/condition assessment project is complete. Included as a Master Plan recommendation is a $50 million placeholder for future inspection/cleaning/repair of the tunnels in the out years of the planning period (FY46-50).

- Older headworks facilities require significant reinvestment that is programmed in the CIP (estimated at $162 million over the next 10 years). Upgrade projects at headworks and facilities across the system will be implemented while systems remain on-line, posing operational challenges.

- MWRA's 20 pump stations and CSO facilities, while generally in good condition, are aging and some are in need of rehabilitation or upgrade. The Master Plan reinvestment strategy for these facilities estimates a $117 million need over the next 10 years, only 25 percent of which is currently programmed in the FY14 CIP.

- No additional CSO capital costs are included (other than maintenance of existing facilities) beyond the planned $49.4 million (FY14-24) to complete the remaining four of 35 projects in the CSO Control Plan and the 3-year CSO control performance assessment. If regulatory action were to mandate a higher level of CSO control, additional capital needs beyond those recommended in the Master Plan would be required.

- The average age of MWRA's 226 miles of gravity sewers is about 65 years old, with about 30 percent over 100 years old. Overall, the collection system is in reasonably good condition, given its age. MWRA's interceptor renewal program targets the approximate 18 miles (8 percent of gravity sewers) that have significant physical defects. The sections requiring repair are prioritized based on risk and consequence of failure and are regularly monitored through internal TV inspection. In addition to the gravity sewers and structures, MWRA also maintains 29 miles of force mains, siphons, and CSO/emergency outfalls. The Master Plan reinvestment strategy for all sewer pipelines estimates a $101 million need over the next 10 years, of which 75 percent is currently programmed in the FY14 CIP.

- Wastewater metering and supervisory control and data acquisition (SCADA) systems will continue to require upgrades based on assumed useful life/obsolescence of the electronic equipment. Much of this equipment is expected to require replacement every 10 to 20 years (estimated at over $14 million for the next 10 years).

- Financial assistance to support member community projects for sewer system rehabilitation and infiltration/inflow reduction is planned to continue but must be evaluated against competing MWRA CIP needs. The Master Plan carries recommended funds for additional community financial assistance, but not beginning until FY19. Accelerating the addition of I/I Local Financial Assistance Program funding is planned to be discussed during the FY15 CIP development process.

The 2013 Master Plan lists programmed and recommended projects with CIP spending in FY14-53 and focuses on projects proposed to require capital spending during the next two 5-year CIP cap cycles: FY14-18 and FY 19-23. Following these two five year periods, potential capital needs during additional 10-year (FY24-33) and 20-year (FY34-53) planning periods are identified. Wastewater System Master Plan project costs for these planning periods are presented in Table 3, below.

TABLE 3 - 2013 Wastewater System Master Plan Cost Summary

	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
Projects Programmed in the FY14 CIP	369,110	500,207	74,308	0	943,625
Projects Recommended for Future CIPs	39,745	139,540	466,750	944,240	1,590,275
Total	408,855	639,747	541,058	944,240	2,533,900

Wastewater System Master Plan projects during the FY14-18 and FY19-23 timeframes are summarized below under five major headings: (1) Wastewater Treatment - Deer Island and Clinton Plants; (2) Residuals Processing (off-island) at the Pellet Plant, (3) Wastewater Headworks and Cross-Harbor Tunnels, (4) Wastewater Pump Stations, CSO Facilities, and CSO Control Plan, (5) Collection System Sewers, SCADA, Metering, and Community Financial Assistance.

Wastewater Treatment - Deer Island and Clinton Plants, FY14-18 and FY19-23

MWRA's Deer Island Treatment Plant (DITP) is the centerpiece of MWRA's $3.8 billion construction program to alleviate pollution in Boston Harbor. The plant provides primary and secondary treatment of wastewater collected from approximately 2.2 million people in 43 greater Boston communities. Treated wastewater effluent is carried by a 9.4-mile, 24-foot diameter outfall tunnel and discharged into the 100-foot deep waters of Massachusetts Bay. DITP is designed to process a maximum of 1.27 billion gallons per day and components include: influent pumps, primary treatment, secondary treatment, disinfection, dechlorination, the outfall tunnel, sludge digesters, odor control, and on-site power generation.

The Deer Island Treatment Plant is the second largest plant in the country in terms of maximum daily capacity. Its multiple treatment processes, high level of automation, and its uniquely-constructed technical and engineering systems present challenges to operating, maintaining, and replacing the plant's equipment, structures, and related support systems. Components of DITP came on-line sequentially beginning in January 1995 with construction completed in 2001. Most plant equipment and structures are up to fifteen years old and in good condition. The Wastewater System Master Plan identifies $215 million in DITP project needs for the FY14-18 timeframe, $188 million programmed in the FY14 CIP and $27 million recommended for consideration in future CIPs. For the FY19-23 timeframe, the Master Plan identifies $237 million in DITP project needs, $221 million programmed in the FY14 CIP and $16 million recommended for consideration in future CIPs. Some major DITP projects during FY14-23 include: pump variable frequency drive replacement, clarifier scum skimmer and rehabilitation phase 2, centrifuge replacement, sludge digester and storage tank rehabilitation, continued electrical equipment upgrades (phase 5), switchgear replacement phase 2, HVAC equipment replacement, fire alarm system replacement, and as-needed design.

The Clinton Advanced Wastewater Treatment Plant (AWWTP) provides advanced sewage treatment services to the Town of Clinton and the Lancaster Sewer District. MWRA upgraded the treatment plant and sludge landfill in 1992 at a cost of $37 million. The plant provides secondary treatment using an activated sludge process in combination with advanced nutrient removal and dechlorination. Effluent is discharged into the South Branch of the Nashua River. The Clinton AWWTP is 20 years old and in generally good condition. Some equipment rehabilitation and replacement projects are recommended; however, significant reinvestment is not required in the short-term. The Master Plan identifies $12 million in project needs for the Clinton Plant for the FY14-18 timeframe, $11 million programmed in the FY14 CIP and $1 million recommended for consideration in future CIPs. Approximately half the FY14-18 budget is allocated to construct new phosphorous removal facilities in anticipation of more stringent phosphorus limits in the draft NPDES permit. The remaining funding is rehabilitation or replacement of equipment. For the FY19-23 timeframe, $4 million is programmed in the CIP and $7 million recommended for consideration in future CIPs for both equipment replacement and technology upgrades to meet future regulatory requirements.

Residuals Processing (off-island) at the Pellet Plant, FY14-18 and FY19-23

Digested sludge is pumped from DITP through two 14-inch, seven mile long force mains that are embedded in concrete within the 11-foot diameter Inter-Island Tunnel and connect to the Residuals Pellet Plant in Quincy. The Pellet Plant was built in 1991 and expanded in 2001 to handle sludge production from DITP secondary treatment facilities. The Residuals Pellet Plant is designed to handle up to 180 dry tons per day of residuals with four of the six operational trains running (current production is 100 to 110 dry tons per day). Pellets are distributed for beneficial reuse. The Pellet Plant is operated and maintained under a long-term contract (March 2001 through December 2015) with a private firm, the New England Fertilizer Company (NEFCo). The annual operating cost is $14 to $16 million per year. Since NEFCo is responsible for all operation, maintenance, and capital improvements for the term of the contract, MWRA has not incurred additional major expenditure at the facility.

In 2015, Pellet Plant equipment will be an average of 20 years old. In July 2010, a comprehensive Residuals Facility Condition Assessment and Utility Reliability project was completed. This project reviewed the adequacy of existing facility components and processes and generally found the facility to be in good to very good condition. In FY13-14, MWRA is conducting an assessment of long-term technology options for residuals processing and disposal beyond 2015. MWRA is also piloting co-digestion to evaluate the impacts of adding food waste, oils, and grease to the digesters at DITP to determine if sludge characteristics are affected. Significant reinvestment is anticipated for residuals processing and disposal during the next 10 years.

The Wastewater System Master Plan identifies $3 million in Residuals Pellet Plant project needs for the FY14-18 timeframe, $2 million programmed in the FY14 CIP and $1 million recommended for consideration in future CIPs. For the FY19-23 timeframe, the Master Plan identifies $98 million in Residuals Pellet Plant facilities upgrade design and construction needs, all of which is programmed in the FY14 CIP.

Wastewater Remote Headworks and Cross-Harbor Tunnels, FY14-18 and FY19-23

MWRA's four remote headworks (Chelsea Creek, Columbus Park, Ward Street, and Nut Island) and 19 miles of cross-harbor tunnels are critical facilities because almost all flow to DITP passes through them. The primary function of the remote headworks is to remove grit and screen out debris from wastewater flow to minimize solids accumulation in the cross-harbor tunnels and protect downstream pump facilities at the DITP. The cross-harbor tunnels (North Metropolitan Relief Tunnel, Boston Main Drainage Tunnel, Inter-Island Tunnel, and Braintree-Weymouth Tunnel) transport wastewater from the remote headworks to Deer Island. The Wastewater System Master Plan identifies $62 million for FY14-18 and $121 million for FY19-23 in remote headworks and cross-harbor tunnel project needs, almost all of which is programmed in the FY14 CIP.

The Chelsea Creek, Columbus Park, and Ward Street Headworks were all built in 1967 and are over 45 years old. Equipment at the headworks was upgraded by MWRA in 1987 and is over 25 years old. These three older facilities remain operational, but, largely due to age and equipment obsolescence, are in only fair condition and need significant reinvestment. A Headworks Condition Assessment/Concept Design project was completed in FY10. This project reviewed the adequacy of existing headworks components and processes and provided replacement/upgrade recommendations based upon current technology. MWRA has developed a prioritized design/construction schedule over the next 10-year period at a cost of over $162 million to rehabilitate the three older remote headworks. Design of upgrades for the Chelsea Creek Headworks began in FY10 and construction is scheduled to run through FY19. The second phase of the project will be to design and construct upgrades for both Columbus Park and Ward Street Headworks together, during FY16-22. The newer Nut Island Headworks, built in 1998, is in very good condition. A group of smaller scale replacement/upgrade projects are planned for the Nut Island Headworks during the short-term ($13 million cost), including work on the mechanical, electrical, grit/screenings, and odor control systems, as well as a study of settlement at the fire pump building.

The North Metropolitan Relief Tunnel and Boston Main Drainage Tunnel were built in 1953 and are 60 years old. The Inter-Island Tunnel (1996) and Braintree-Weymouth Tunnel (2005) are relatively new. Based on the industry benchmark of 100+ years for useful life for tunnels, it is assumed that the older cross-harbor tunnels are still in good condition. However, the existing condition of the tunnels is unknown; therefore, there is uncertainty associated with the potential for future repair/rehabilitation and risk of a very large future cost. Some deterioration of concrete in the tunnel shafts has been documented and attributed to hydrogen sulfide corrosion. Since the cross-harbor tunnels and shafts are critical facilities, a study of the effluent shafts, as well as a tunnel inspection and shaft repair project are a high priority. These projects are programmed in the FY14 CIP at $5 million during FY19-21.

Wastewater Pump Stations, CSO Facilities, and CSO Control Plan, FY14-18 and FY19-23

The MWRA collection system includes 13 pump stations, one screening facility, and six CSO treatment/storage facilities. The primary function of a pump station is to lift wastewater from an upstream sewer (at a lower elevation) to a downstream interceptor (at a higher elevation) so the wastewater can continue to flow by gravity to MWRA headworks facilities. Most pump stations operate continuously; however, two MWRA pump stations (Framingham and New Neponset Valley Sewer Pump Stations) are designed to operate during peak flows (wet weather) only. The primary function of a combined sewer overflow (CSO) facility is to store and/or treat combined (sanitary and stormwater) flow that exceeds the capacity of the combined sewer system in large rainfall events.

The average age of MWRA's 20 collection system facilities is 21 years. Only five of the 20 facilities are more than 25 years old. The oldest pump station, Alewife Brook in Somerville, is 61 years old. Two of MWRA's CSO facilities are 41 years old: the Cottage Farm Pumped CSO Facility and the Somerville Marginal Gravity CSO Facility. Overall, the 20 collection system facilities are in good condition. Significant automation upgrades were implemented under MWRA's Wastewater Central Monitoring/SCADA Implementation Project during 2007-2009. The CSO facilities have undergone upgrades under the CSO Control Plan and two of the former CSO stations (Commercial Point and Fox Point) were decommissioned in 2008 following completion of local sewer separation projects. The highest priority immediate needs for wastewater pump stations and CSO facilities are rehabilitation/replacement projects being implemented at the 10 older facilities.

For wastewater pump stations and CSO facilities, the Wastewater System Master Plan identifies $31 million in project needs for the FY14-18 timeframe, $28 million programmed in the FY14 CIP and $3 million recommended for consideration in future CIPs. For the FY19-23 timeframe, the Master Plan identifies $86 million in wastewater pump stations and CSO facilities needs, none of which has been programmed in the FY14 CIP. Some major projects during FY14-23 include: ongoing rehabilitation construction at the Alewife Brook Pump Station; a condition assessment for the 10 oldest wastewater facilities; and follow-up design and construction of upgrades at the oldest stations (Alewife Brook, Caruso, Chelsea Screen House, DeLauri, Hayes, Hingham, Prison Point, Wiggins - Castle Island Terminal, Cottage Farm, and Somerville Marginal).

MWRA's Long-Term CSO Control Plan, as mandated by the Federal Court, is comprised of 35 wastewater system improvement projects that address 84 CSO outfalls. As of July 2013, MWRA and its CSO communities had completed 31 of the 35 projects in the CSO long-term control plan, two projects were well into construction, and the remaining two projects were in design with construction starts scheduled in September 2013 and August 2014. The Federal Court schedule requires MWRA to commence a 3-year performance assessment in January 2018 (approximately two years after the last of the 35 CSO projects is scheduled to be complete) and submit a report assessing attainment of the long-term levels of control by December 2020. The Master Plan includes details on project engineering and construction requirements, schedules, long-term levels of CSO control, status of work to implement the plan, benefits achieved to date, and future activities. The total cost of the CSO Control Plan (including both previous and future expenditures) is $888 million, of which $839 million (94 percent) was expended through FY13. The FY14 CIP includes $49 million in spending during FY14-24 to complete the remaining four of 35 projects in the CSO Control Plan and the 3-year CSO control performance assessment. There are no future MWRA or community-managed CSO Control Plan projects recommended for consideration in future CIPs. Funds to replace equipment at CSO facilities are included in collections system facilities costs.

Collection System Sewers, SCADA, Metering, and Community Financial Assistance. FY14-18 and FY19-23

The primary function of the collection system is to transport wastewater received from the 43 member sewer communities (through over 1,800 community connections) to the MWRA headworks facilities. Collection system operations are intended to optimize system performance and minimize potential CSOs and SSOs, particularly before and during storm events that stress the system's hydraulic capacity. The collection system includes a network of 274 miles of sewer pipelines - 19 miles of cross-harbor tunnels, 226 miles of gravity sewers, 18 miles of force mains, 7 miles of siphons, 4 miles of CSO and emergency outfalls, and 4,000 manholes and other structures. Internal inspection information (physical, television, and sonar) is used to develop maintenance schedules, identify structural problems, and help define rehabilitation projects.

For collection system sewers, supervisory control and data acquisition (SCADA) systems, wastewater metering, and community financial assistance, the Wastewater System Master Plan identifies $38 million in project needs for the FY14-18 timeframe; $31 million programmed in the FY14 CIP and $7 million recommended for consideration in future CIPs. For the FY19-23 timeframe, the Master Plan identifies $85 million in collection system needs, $55 million programmed in the FY14 CIP and $30 million recommended for consideration in future CIPs. Some major projects during FY14-23 include: a series of prioritized interceptor renewal/asset protection projects ($31 million); a series of sewer corrosion and odor control projects ($12 million); sewer siphon structure, manhole, and force main rehabilitation ($18 million); SCADA and wastewater metering ($14 million); and member community financial assistance ($7 million).

The average age of the sewer system is about 65 years old. Approximately 30 percent of sewers are over 100 years old; however, the collection system is in reasonably good condition given its average age. Based on internal TV inspection ratings for gravity sewer pipe, approximately 70 miles (31 percent) are new or are in very good condition (A-rated), 139 miles (61 percent) are in fair to good condition with some damage (B-rated), and 18 miles (8 percent) of interceptors are severely damaged (C-rated). The most critical need for the sewer system is rehabilitation construction that will address long-term sewer asset protection for C-rated pipelines. To meet this need, MWRA developed a series of prioritized interceptor renewal/asset protection projects. The gravity sewer inspection ratings have not been used for force mains, siphons, or outfalls; however, based on available data, these also appear to be in reasonably good condition. MWRA continues to monitor hydrogen sulfide corrosion and odor issues in the collection system to prioritize inspections for affected sewers. TRAC staff oversee the pre-treatment work of municipalities and industries. The Wastewater System Master Plan does not include recommendations for future large scale capital projects to target capacity/optimization projects related to extreme event SSOs. Effective use of future capital resources to address extreme event SSOs will be investigated within the ongoing and recommended modeling/planning studies.

The SCADA systems provide a means of monitoring and controlling facilities and equipment from a remote centralized location, as well as providing a continuous record of facility operations. MWRA's Wastewater SCADA system went through a major upgrade from 2007 through 2009 as part of the Wastewater Central Monitoring/SCADA Implementation Project. This project created a unified SCADA system covering all significant wastewater facilities. New facilities have been incorporated into the system. All wastewater facilities can be monitored and controlled at the Chelsea Operations Control Center using the SCADA system. MWRA's wastewater metering system provides rate-basis data on community flows, as well as additional operational support data for hydraulic modeling, capacity analyses, engineering studies, and community flow component (sanitary/infiltration/inflow) estimates. Upgrades to the SCADA and wastewater metering systems are scheduled to continue throughout the 40-year Master Plan schedule.

Since 1993, MWRA has made a commitment to assist member sewer communities to finance infiltration and inflow (I/I) reduction and sewer system rehabilitation projects within their locally-owned collection systems. Funding of community projects through MWRA's I/I Local Financial Assistance Program is provided as 45 percent grants and 55 percent interest-free five year loans. The program goal is to assist member communities in improving local sewer system conditions to reduce I/I and ensure ongoing repair/replacement of the collection system. It is a critical component of MWRA's Regional I/I Reduction Plan. The FY14 CIP includes a net cost of $7 million (including loan repayments) for approved local distribution through FY21. The Master Plan includes placeholders for five additional rounds ($40 million in grant/loans in each round) of CIP funding beginning in FY19 at a net cost of $18 million each. For the FY14-53 timeframe, a total of $84 million is identified for community financial assistance.

Attachment A

2013 Water System Master Plan - Summary of Existing and Recommended Projects by Chapter

Last revision 10/31/13

Project	Cost ($1000)	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
		5 years	5 years	10 years	20 years	
SUBTOTAL - Existing - Land Acquisition - Chapter 5	6,000	6,000	0	0	0	6,000
SUBTOTAL - Recommended - Land Acquisition - Chapter 5	35,000	0	5,000	10,000	20,000	35,000
SUBTOTAL - Existing - Water Treatment - Chapter 6	25,180	25,101	79	0	0	25,180
SUBTOTAL - Recommended - Water Treatment - Chapter 6	53,500	0	7,500	19,000	27,000	53,500
SUBTOTAL - Existing Projects - Transmission and Dams - Chapter 7	426,375	74,135	233,502	118,738	0	426,375
SUBTOTAL - Recommended - Transmission and Dams - Chapter 7	91,825	0	6,100	31,725	54,000	91,825
SUBTOTAL - Existing - Metropolitan System - Chapter 8	598,962	188,319	301,063	99,674	9,906	598,962
SUBTOTAL - Recommended - Metropolitan System - Chapter 8	170,700	0	10,500	103,500	56,700	170,700
SUBTOTAL - Existing - Community Assistance - Chapter 8	(118,000)	3,000	(50,000)	(71,000)	0	(118,000)
SUBTOTAL - Recommended - Community Assistance - Chapter 8	0	0	54,000	63,000	(117,000)	0
SUBTOTAL - Existing - Ancillary Services - Chapter 9	6,987	6,815	172	0	0	6,987
SUBTOTAL - Recommended - Ancillary Services - Chapter 9	54,200	5,370	10,330	15,200	23,300	54,200
SUBTOTAL - Existing - Energy - Chapter 10	9,194	5,542	3,652	0	0	9,194
SUBTOTAL - Recommended - Energy - Chapter 10	0	0	0	0	0	0
SUBTOTAL - Existing - ALL with Community Assistance	954,698	308,912	488,468	147,412	9,906	954,698
SUBTOTAL - Recommended - ALL with Community Assistance	405,225	5,370	93,430	242,425	64,000	405,225
SUBTOTAL - Existing - ALL without Community Assistance	1,072,698	305,912	538,468	218,412	9,906	1,072,698
SUBTOTAL - Recommended - ALL without Community Assistance	405,225	5,370	39,430	179,425	181,000	405,225
TOTAL	1,477,923	311,282	577,898	397,837	190,906	1,477,923

Attachment B

2013 Wastewater System Master Plan - Summary of Existing and Recommended Projects by Chapter

Last revision 9/9/13

Project	Cost ($1000)	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
		5 years	5 years	10 years	20 years	
SUBTOTAL - Existing Projects - Deer Island - Chapter 6	456,820	188,385	221,679	46,756	0	456,820
SUBTOTAL - Recommended - Deer Island - Chapter 6	689,700	27,250	15,700	199,750	447,000	689,700
SUBTOTAL - Existing - Residuals - Chapter 7	103,458	1,549	98,237	3,672	0	103,458
SUBTOTAL - Recommended - Residuals - Chapter 7	82,320	1,320	0	3,000	78,000	82,320
SUBTOTAL - Existing - Headworks and Tunnels - Chapter 8	182,817	62,256	120,561	0	0	182,817
SUBTOTAL - Recommended - Headworks and Tunnels - Chpater 8	110,500	0	500	25,000	85,000	110,500
SUBTOTAL - Existing - Sewers - Chapter 9	92,818	22,249	51,829	18,740	0	92,818
SUBTOTAL - Recommended - Sewers - Chapter 9	282,400	7,400	20,000	128,000	127,000	282,400
SUBTOTAL - Existing - Pump Stations and CSO Facilities - Chapter 10	27,965	27,621	344	0	0	27,965
SUBTOTAL - Recommended - Pump Stations and CSO Facilities - Chapter 10	288,000	3,000	86,000	56,000	143,000	288,000
SUBTOTAL - Existing - CSO Control Plan (MWRA and Community Managed) - Chapter 11	49,400	48,066	1,271	63	0	49,400
SUBTOTAL - Recommended - CSO Control Plan (MWRA and Community Managed) - Chapter 11	0	0	0	0	0	0
SUBTOTAL - Existing - SCADA and Metering - Chapter 12	22,000	6,231	7,692	8,077	0	22,000
SUBTOTAL - Recommended - SCADA and Metering - Chapter 12	20,480	0	240	5,000	15,240	20,480
SUBTOTAL - Existing - Clinton - Chapter 14	14,347	10,753	3,594	0	0	14,347
SUBTOTAL - Recommended - Clinton - Chapter 14	26,875	775	7,100	9,000	10,000	26,875
SUBTOTAL - Existing - Community Support - Chapter 15	-6,000	2,000	-5,000	-3,000	0	-6,000
SUBTOTAL - Recommended - Community Support - Chapter 15	90,000	0	10,000	41,000	39,000	90,000
SUBTOTAL - Existing - ALL	943,625	369,110	500,207	74,308	0	943,625
SUBTOTAL - Recommended - ALL	1,590,275	39,745	139,540	466,750	944,240	1,590,275
TOTAL	2,533,900	408,855	639,747	541,058	944,240	2,533,900

1 Introduction

1.1 Overview of MWRA

The Massachusetts Water Resources Authority (MWRA) was established by the Massachusetts Water Resources Authority Act, Chapter 372 of the Acts of 1984 of the Commonwealth of Massachusetts. In 1985, responsibility for water distribution for 46 municipalities and sewage collection and treatment for 43 municipalities was transferred from the Metropolitan District Commission (MDC) to the MWRA. MWRA's facilities span from the Quabbin Reservoir in western Massachusetts to the Deer Island Treatment Plant in Boston Harbor. Approximately 2.5 million people, about 44% of the total population of Massachusetts, live in the communities served in whole or in part by the MWRA.

MWRA is an independent public agency with the ability to raise its revenues from ratepayers, bond sales and grants. In addition to its operating responsibility, the MWRA was created to modernize the area's water and sewer systems and clean up Boston Harbor. MWRA's long-term business plan emphasizes improvements in service and systems and includes aggressive performance targets for operating the water and wastewater systems and maintaining new and existing facilities. Parallel to MWRA's goal of carrying out its capital projects and operating programs is its goal of limiting rate increases to its customer communities. The need to achieve and maintain a balance between these two goals is a critical issue in the development of both the Water System and Wastewater Master Plans. MWRA maintains an extensive website at mwra.com that provides information on the development of the agency, organization of the Authority, water and sewer systems, customer communities, agency finances, etc.

1.2 Purpose of the Water System Master Plan

MWRA's Water System Master Plan presents a long-term vision of the capital development needs of the water system and the actions planned for the next forty years to meet those needs. The primary purpose of this Plan is to ensure that key staff from across the Authority engage in proactive planning to enhance system performance while minimizing long-term costs to MWRA ratepayers. The treatment and delivery of water to a major region of the state (over 2 million customers) represents an essential public service. It is the MWRA's responsibility to protect public health, promote environmental quality improvements, support a prosperous economy, maintain customer confidence, and minimize sewer charges. To fulfill this responsibility, significant expenditures for system rehabilitation and improvements will continue. This Water System Master Plan identifies system/facility conditions, operational risks and capital project needs. The Master Plan accounts for all projects included in the FY13 CIP, and newly-identified projects. Budgets and schedules for those projects have been updated to reflect the approved FY14 CIP. Projects have been prioritized and a recommended implementation timetable developed that corresponds with MWRA's annual CIP development cycle.

Concurrent with this update to the Water System Master Plan, the MWRA is also updating the Wastewater Master Plan. The preparation of updated Master Plans was recommended by the MWRA Advisory Board in order to provide a more thorough context for developing, analyzing, and evaluating the annual Capital Improvement Program (CIP). These updated plans are intended to serve as an important tool for future planning, budgeting and rate setting decisions.

1.3 Planning Approach, Assumptions and Time Frame

In its two-decade existence, MWRA has constructed billions of dollars of facilities to repair, replace, and modernize aging infrastructure. The $1.7 billion Integrated Water Supply Improvement Program greatly improved the quality and reliability of MWRA's water treatment and transmission system consistent with federal and state Safe Drinking Water Act requirements. The estimated replacement value of MWRA's water system assets is over $6 billion. MWRA is now in transition with a need to rehabilitate those portions of the system that have not been replaced and provide for maintenance and asset protection of newer facilities. Development of the Master Plan will continue the transition with respect to capital projects, shifting MWRA's primary focus from construction of new facilities to maintenance and rehabilitation/replacement.

For the 2013 Master Plan, MWRA has selected a 40-year planning period through FY53. The Master Plan focuses on projects included in the FY14 CIP and newly recommended projects that are proposed to generate capital spending during the next two 5-year CIP cap cycles FY14-18 and FY19-23. Estimates of project costs and schedules over this shorter term are expected to be more reliable than looking ahead to the out-years. Following these two 5-year periods, additional 10-year (FY24-33) and 20-year (FY34-53) planning periods are utilized.

As will be explained in the specific chapters, a number of assumptions were made based on the information gathered for this plan and these assumptions explain why certain financial needs are not identified. The analyses summarized in Chapter 4 indicate that source capacity (the 300 MGD safe yield of the MWRA system) is sufficient to meet future demand for water both within the service area and additional demand outside of the existing service area as may be approved. Finally, at this time, no design and construction funds are included to address the impacts on MWRA's water system of potential changes in federal or state regulations.

All projects have been prioritized on a scale from 1 to 5, with 1 being projects considered critical and 5 considered desirable. Priorities for the water projects reflect the water system goals and objectives found in Chapter 2 of this plan. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will improve system reliability including the elimination of "single points of failure". Projects that will provide critical condition assessment information were also considered high priority. Lower priority projects will monitor long-term system needs and provide more efficient operation. Project ratings were assigned by MWRA senior managers in concert with Planning and Coordination Department staff. All MWRA capital projects will be further reviewed and priorities will be reconsidered during the development process for future CIPs.

1.4 Organization of the Master Plan

The 2013 Water System Master Plan is organized into chapters for distinct topics and/or separate asset classes (such as the Transmission System, Treatment, and the Metropolitan System etc.). Each chapter that recommends capital projects includes a summary section that provides an overview of major findings, recommendations, costs, and project schedules. The 2013 Wastewater System Master Plan has been compiled in a separate volume. The Master Plan Executive Summary presents the combined existing and recommended capital projects for both water and wastewater.

1.5 Periodic Updates

The Water System Master Plan is intended to represent an ongoing process; it is not intended to be a static document. The Plan presents a broad range of recommended projects, some critical (to be completed in the short-term) and some lower priority (to be completed in the long-term). Changes in scope, details and scheduling of certain projects may be required over time to respond to emergencies, new regulations, emerging technologies, etc. Although this Plan will map out major expenditures for the water system for many years, conditions change and flexibility is important. The Plan is intended to be reviewed annually as an integral component of MWRA's Capital Improvement Program development and will be revised periodically to reflect new initiatives and/or major changes in priorities. A complete Master Plan review/update is recommended to be performed no less than every five years.

2 Water System Goals and Objectives

2.1 Planning Goals and Objectives Defining MWRA's Water System Mission

MWRA's mission is to provide reliable, cost-effective, high-quality water and sewer services that protect public health, promote environmental stewardship, maintain customer confidence, and support a prosperous economy.

MWRA's fundamental mission regarding water service delivery is established in the Enabling Act: to reliably and efficiently deliver an adequate quantity of high quality water to the customer communities, and to properly manage, repair, rehabilitate, and improve the waterworks system so that its service requirements can be met. For the purposes of setting priorities among needs and guiding the planning process, this basic mission is articulated in four distinct principles:

- Provide reliable water delivery.
- Deliver high quality water.
- Assure an adequate supply of water.
- Manage the system efficiently and effectively.

Since these principles represent basic goals and ideals for operating and caring for the water system, further definition of objectives is necessary to establish how MWRA intends to satisfy these goals.

OBJECTIVES

Guidance on the application of each principle is provided by a set of objectives. The objectives express the philosophy and emphasis for program planning and project implementation and identify where efforts should be focused and what approaches should be followed in assessing conditions and developing solutions. These objectives reflect both MWRA's current understanding of the needs and priorities of the system but also the need to be cognizant of potential future changes. These changes may be internal to MWRA or they may be driven by external events, such as regulatory changes or changes in member community priorities.

Individual projects identified during the master planning process will be evaluated at a threshold level in the context of how they meet the stated objectives. However, once projects have been identified and determined to meet specific objectives, their relative prioritization for inclusion in the capital budget will be the result of a more targeted analysis.

2.2 Provide Reliable Water Delivery

Dependable and continuous water delivery at adequate pressures and flow rates is an essential public service integral to the public health, safety, and economic well-being of the region's population. It is MWRA's goal to secure, operate and maintain the water system as needed so that the potential for supply interruption within the service area is kept to an absolute minimum. Disruptions will inevitably occur but fundamental water supply principles prescribe that the consequences of such disruptions be managed and that secondary modes of delivery be available in the event that primary modes are taken off-line for servicing or due to breakdown. Distribution storage sufficient to prevent or minimize significant supply disruptions must also be developed in order to reduce risk. MWRA also recognizes its role to provide wholesale water service in a manner that supports the communities' abilities to meet local requirements for pressure and fire flows. In general, water pressures at community meters should be within an appropriate range at all times and flow rates should be capable of satisfying maximum rates of demand.

Objectives

1) Fix existing reliability problems related to "single points of failure": MWRA has developed information through emergency planning and vulnerability assessments on those points within the transmission and distribution systems where a component failure or shut-down could lead to a disruption in service. The next step is to develop remedies that provide secondary modes of delivery at these locations or develop appropriate emergency response plans. MWRA should continue to move forward with design of distribution system projects that improve redundancy, particularly in the NIH and SEH pressure zones, and with the major distribution and transmission system projects that address redundancy needs for the Cosgrove and Metro area tunnels.

2) Fix facilities in poor condition: MWRA has made significant progress in the identification and rehabilitation of operating and emergency facilities where mechanical or other systems were in poor condition. These facilities will need to be continually evaluated and renewed at regular intervals. Pipeline rehabilitation and replacement must continue in order to address key assets that are in poor condition or are hydraulically deficient and are thereby compromising the system's ability to provide uninterrupted service or adequate flow, or that may potentially contribute to poor water quality. In addition, work to identify and implement dam maintenance and rehabilitation needs should continue during this next five-year Master Planning period.

3) Increase and maintain distribution storage: Continue to implement the recommendations of the 1993 "Water Distribution System Storage Study", and the 1993 and 2006 Water System Master Plans relative to the development of additional distribution storage. Although the volume of system-wide storage has increased, specific areas of the distribution system do not have sufficient localized distribution storage. Storage requirements should also be considered when addressing potential system expansion requests.

4) Use effective planning and preventive maintenance to minimize risks: In order to reduce the risk of failure, implement systems and preventive maintenance practices to identify, monitor, maintain and replace key equipment in an orderly way to reduce the risk of service

disruptions. Continue successful programs that reduce risks such as valve exercising, valve rehabilitation and replacement, and leak detection efforts. Expand measures, where appropriate, to reduce the likelihood of pipeline corrosion due to stray current.

5) Support work force safety: Provide adequate workplace and field site conditions, and equip crews with the tools, materials and information necessary to carry out operational and maintenance duties safely. Consider staff safety when making decisions about maintenance activities and process technologies.

6) Monitor the system: Continue to implement and enhance measures that allow 24/7 monitoring of key system components. Track upgrades to existing technologies and follow emerging technologies for applicability to the MWRA system.

2.3 Deliver High Quality Water

Since its inception, MWRA has invested significant funds into water quality/treatment improvements to ensure that the customer communities receive water that meets all governmental standards. Provision of high quality water involves four key elements: source water protection, effective and reliable treatment, prevention of water quality degradation in the distribution system and monitoring. In addition, because it is critical that consumers maintain confidence in the quality of their tap water, MWRA should continue to provide a water product which has a consistent and appealing character, and does not arouse doubts about its quality and healthfulness.

Objectives

1) Protect public health: Deliver water that meets, or is better than, the quality standards set by federal and state regulations. Since regulatory standards may lag scientific knowledge, monitor emerging trends in public health protection. As appropriate, implement contaminant warning systems.

2) Preserve water quality within the distribution system: Maintain treatment process equipment to minimize risk of treatment disruptions. Continue to aggressively rehabilitate or replace remaining MWRA unlined pipe that tends to be in poor condition and that degrades water quality and continue to provide financial support to cleaning and lining and other rehabilitation efforts in the community distribution systems. Size, maintain and operate storage facilities to ensure protection from potential pollutants and to avoid stagnation. Where appropriate, consider implementation of preventive measures such as corrosion protection that can extend asset life.

3) Follow drinking water legislation and regulations: Closely follow the development of and any modifications to drinking water legislation and regulations, and actively represent the MWRA's interests in order to maximize our options and to ensure that resulting water quality requirements are reasonable and appropriate for our situation. Where appropriate, pursue flexible planning strategies that maximize opportunities for selecting treatment methods that are cost effective, meet regulatory requirements and that provide the most value and return in terms of public health benefits and water quality enhancement.

4) Implement the MOU with DCR: Continue to work with the Department of Conservation and Recreation (DCR) in order to maintain excellent source water quality. Develop budget and project priorities to ensure the prevention of contamination, and to provide strong support for DCR protection and watershed monitoring efforts. Continue to review and implement appropriate measures to address security concerns relative to water quality.

5) Ensure customer confidence: Recognize the importance of ensuring consumer confidence in the quality of water at the tap, and promote greater awareness of what can be done to prevent water quality deterioration within community and household pipes. Develop clear, understandable information and educational materials for consumers.

2.4 Assure an Adequate Supply of Water

As a regional water supply utility, the Authority maintains a fundamental goal of ensuring that enough water is available to reliably meet water needs within the areas served. Under normal circumstances, this means that water needs should not exceed the safe yield of existing supplies. MWRA's source reservoirs, the Quabbin and Wachusett, can be counted on to safely provide about 300 million gallons per day (mgd) of water. For a 20-year period from 1969 to 1988, the customers of MWRA (and its predecessor MDC) routinely drew more than the safe yield. To address this problem, MWRA launched an aggressive water conservation program in 1986. By 1989, withdrawals were below the safe yield, where they have remained and have continued to drop over time. Demand on the MWRA Waterworks system was 200 mgd in 2012 and the five-year running average for system withdrawals is also 200 mgd. A flow policy and regulatory scheme that may emerge from the State's Sustainable Water Management Initiative may result in restrictions on the expansion of various local water supplies. In the long run, to accommodate growth, there may be more reliance on a regional water management approach that capitalizes on the capacity of MWRA's large storage reservoirs.

Objectives

1) Periodically review water needs: Base water needs assessments on demand forecasts that incorporate realistic assumptions about service area population, usage factors, and local source availability including consideration of how those local sources may be impacted by climate change.

2) Maintain demand management efforts: Continue to provide educational materials to communities and to individuals. Maintain management controls to monitor community and system use in order to identify and investigate any unanticipated increases in water use. Continue to support leak detection efforts for both the MWRA system and the community systems.

3) Review Opportunities for System Expansion: Look for opportunities to use excess MWRA capacity to provide environmental benefits, particularly in the headwaters of stressed river basins and within MWRA's watersheds. Consider current and anticipated system demands and the requirements of MWRA's Enabling Act and MWRA policies.

4) Encourage the protection of local sources: Encourage continued local source protection efforts by local communities.

5) Monitor supply conditions and manage drought conditions responsibly: Use a planning approach which monitors key data, preserves options and allows for timely decisions and actions as needed to effectively respond to changing conditions. In the event of actual or impending drought conditions, follow the actions and responses in the Drought Management Plan and seek full cooperation from customer communities. Continue to maintain a high degree of supply reliability so that drought restrictions are not imposed on the public too frequently or for long periods of time.

2.5 Manage the System Efficiently and Effectively

The Authority recognizes its responsibility as a public entity to manage the water system efficiently and effectively. This means that operations are to be conducted safely and appropriately, and that careful attention will be given to efficiency, sustainability of resources and cost-effectiveness in order to provide the greatest value to the ratepayers while meeting our standards for service.

Objectives

1) Minimize water losses and waste: Seek to continually improve water distribution efficiency by minimizing water losses, waste, and in-system consumption.

2) Implement sustainable and energy efficient practices: Continue to consider opportunities to reduce the energy used to operate the MWRA water system; purchase renewable power where appropriate; and, continue to develop solar, wind and hydroelectric facilities at locations within the water system as are determined to be feasible.

3) Maintain and enhance measurement and monitoring technologies: Continue to support measurement and monitoring technologies, including SCADA, to facilitate the accurate measurement and monitoring of flow conditions for the purposes of water accountability, determining community consumption levels, monitoring system status, flood control and developing data for analysis and planning. Review new technologies and implement system upgrades as appropriates for improved monitoring and/or control of certain water system facilities that will yield benefits in terms of operational efficiency and flow control precision.

4) Support work force productivity: Support the productivity of the work force by providing adequate workplace and field site conditions, and equipping crews with all necessary tools, materials and training necessary to carry out operational, maintenance, and repair duties cost-effectively and efficiently. Move forward with MWRA succession planning efforts to ensure a continuity of operations.

5) Update and refine mapping and modeling tools as appropriate: Use up-to-date modeling and mapping tools to facilitate system analyses and decision making. Support records management activities that promote the documentation of accurate, comprehensive and up to

date information on the MWRA system, including development of record drawings for those assets where no record drawings currently exist. Compile and organize the data and provide access to appropriate staff.

6) Optimize system operations: In designing long-term improvements, look for opportunities to optimize the operation of the system. Thoroughly review proposed engineering solutions to ensure that proposed projects will not negatively affect hydraulic performance. Aim to satisfy service area pressure requirements more efficiently by taking advantage of available hydraulic gradients within the transmission system, and by minimizing the usage of pumped water in areas where it is not necessitated by geographic conditions.

3 Water System History, Organization and Key Infrastructure

3.1 The Beginning - The Water System

Boston's water supply system has had a remarkable progression dating back as far 1630 when the City was first settled and relied on water from cisterns and wells. As the City grew, so did its need to provide sufficient clean sources of water for a growing population. The pattern of looking west beyond the city for larger and cleaner water supplies repeated itself over and over again. Beginning as early as 1795**,** Jamaica Pond was tapped to provide adequate water sources for metropolitan Boston, followed by Lake Cochituate in Wayland in 1846, then, the Mystic Lakes in 1870, and subsequently, the Sudbury River (shown below) in 1872 (See Figure 3-1 for chronology). At the same time, in order to ensure that there were adequate conveyance systems in place to transport the water resources, significant construction projects including the Cochituate, Mystic, and Sudbury aqueducts were completed. Boston began development of its distribution system in 1848 with the introduction of Lake Cochituate water via a system of cast iron pipes, open distribution reservoirs and, eventually, pumping stations. Other metropolitan area communities installed water works in the late 1800's such that there were already thousands of miles of smaller pipes and a variety of local sources in place by the end of the century. Poor water quality and limited yield of some of these sources, like the heavily polluted Mystic Lakes, became an issue.

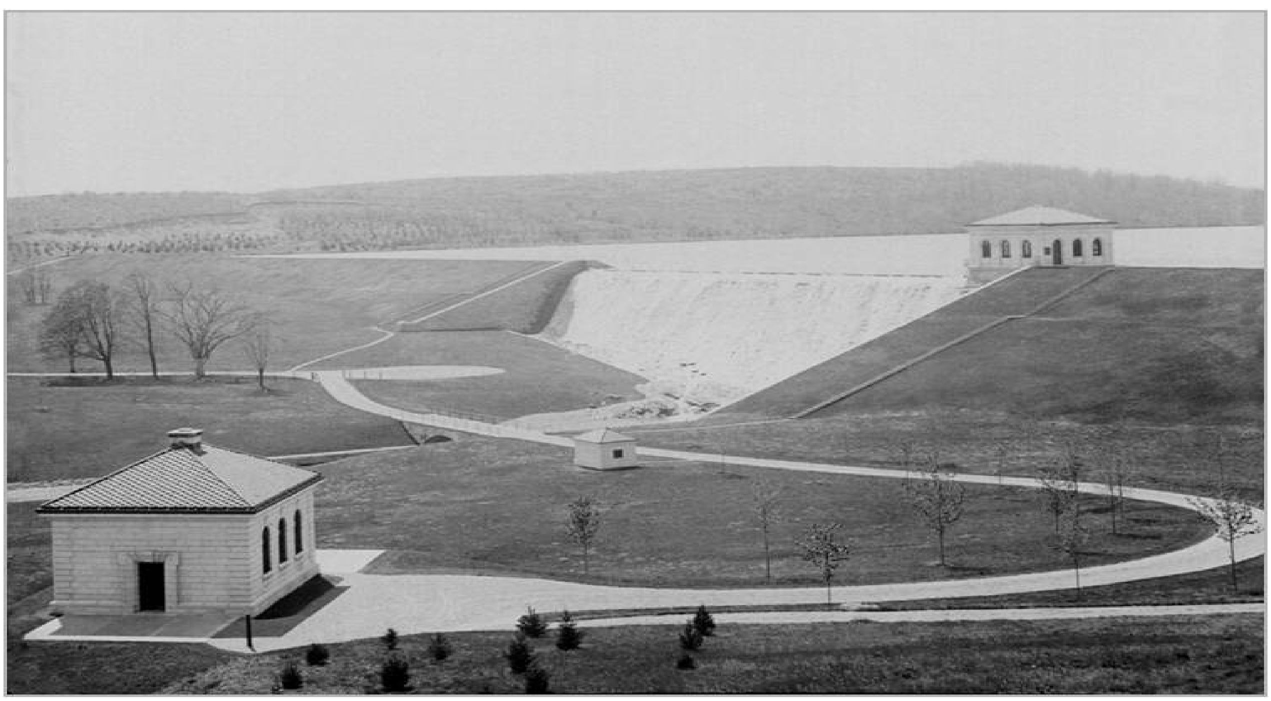


Figure 3-1 Development of the Metropolitan Water System

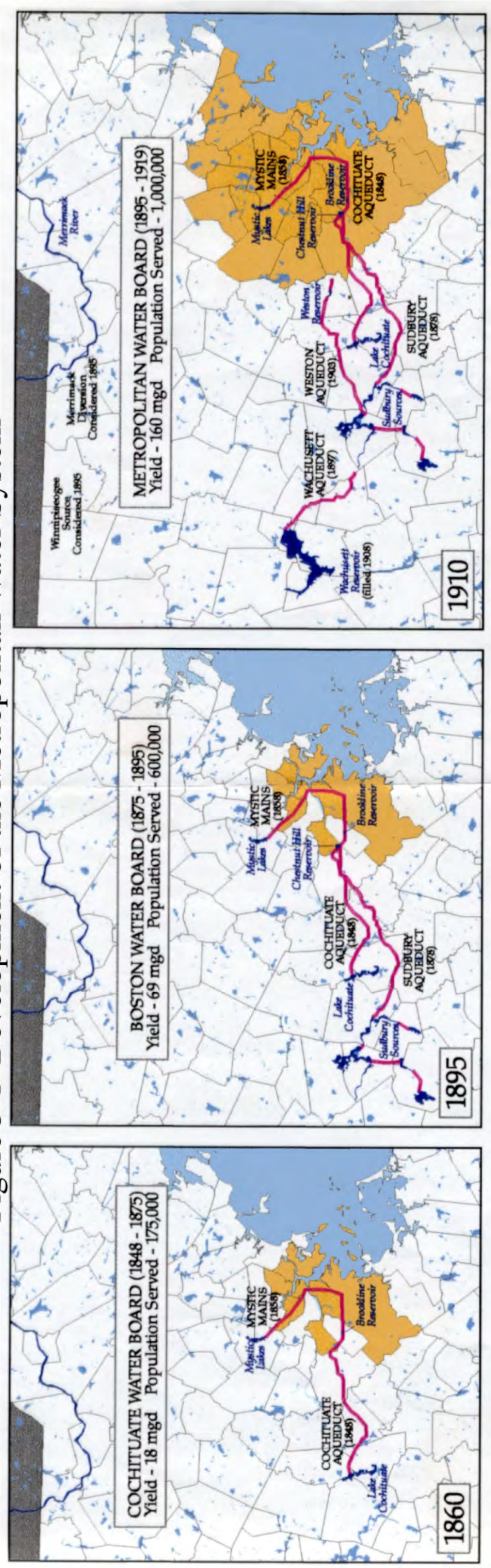
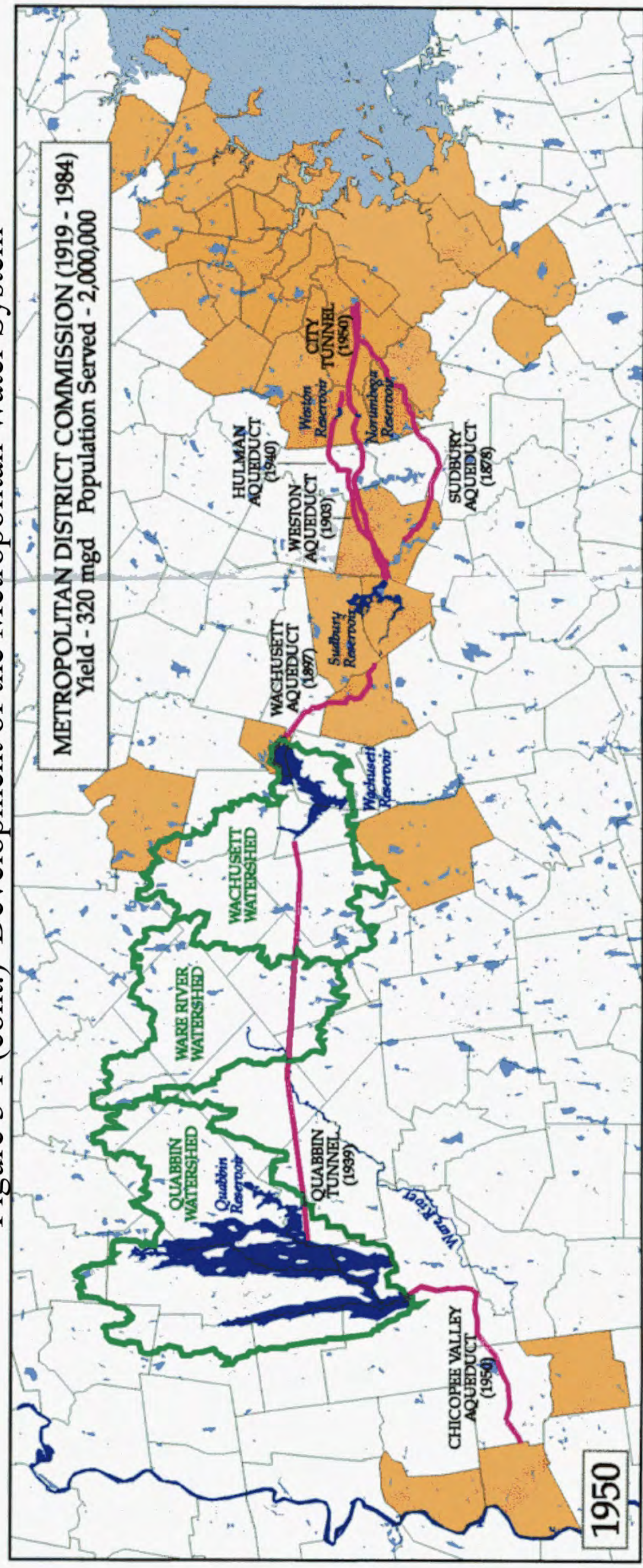


Figure 3-1 (cont.) Development of the Metropolitan Water System



By 1895, in response to continuing growing needs spurred by population growth, the industrial revolution, and increased fire protection needs, Boston's expanding water supply system became one of the first in the nation to be integrated into a multi-municipality Metropolitan water district governed by the newly created Metropolitan Water District and Metropolitan Water Board. These two entities later became the Metropolitan Water and Sewerage Board in 1901. Understanding the need for future planning and the need for additional water supply sources, the Board directed the construction of the Wachusett Reservoir (65 billion gallons) in 1907 which served as the principal water supply for metropolitan Boston. After World War I, it became apparent that Wachusett Reservoir would be insufficient to meet water supply needs and the State Legislature commissioned a major study in 1919 to examine other water supply sources. Later that same year, the Legislature also felt the need to create a new agency, the Metropolitan District Commission (MDC) which consolidated responsibility for metropolitan water, sewage, and parks into one agency in 1926.

The Quabbin Tunnel, a 24 mile long deep rock tunnel was completed in 1939 to eventually transport water from the Quabbin Reservoir to the Wachusett Reservoir. The tunnel is also used to divert water west from the Ware River into the Quabbin when such diversions are permitted. In 1944, the MDC completed the construction of the 17.8 mile Hultman aqueduct to augment the old brick aqueduct system. The Hultman was built to deliver clean water directly from the Wachusett Reservoir to the Boston area. It was under the direction of the MDC and their visionary engineers that the last major expansion to the water supply system was finished in 1946, with the filling of the 412 billion gallon Quabbin Reservoir (Figure 3-2). While the creation of the Reservoir brought many benefits to watershed protection and water supply for metropolitan Boston, it was not without loss. The Quabbin Reservoir was created by flooding the Swift River Valley eliminating the towns of Dana, North Dana, Greenwich, Enfield, and Prescott, Massachusetts and is one of the largest manmade reservoirs in the country accommodating over two million people in 51 cities and towns daily.

It would be another 66 years until another agency would be created to succeed the MDC in overseeing the metropolitan Boston's water and sewer system needs when in 1984 the Massachusetts Water Resources Authority (MWRA) was created.

3.2 MWRA

Created by the State Legislature in 1984 as an independent public authority, MWRA assumed responsibility for the delivery and distribution of water to 46 communities (now 51 after recent additions). What made MWRA different from its' predecessor, the MDC, was the fact that MWRA had the ability to sell bonds and raise revenues to hire essential staff, undertake major capital projects like the Boston Harbor Project and MetroWest Tunnel, as well as handle essential day-to-day routine operation and maintenance.

MWRA is governed by an 11-member Board of Directors who are appointed by the Governor or directly or indirectly by elected officials in MWRA customer communities. Eight of the 11 members of MWRA's Board of Directors are directly or indirectly appointed by the 61 customer communities. Three members are appointed by the Governor.

Today, the water system is managed as a partnership with the Department of Conservation and Recreation (DCR) (formerly MDC), which still maintains responsibility for managing the reservoirs and watersheds. At MWRA, much of the work described in the Water System Master Plan is carried out by the Operations Division under a variety of interrelated departments including: Water and Wastewater Operations and Maintenance, Water Distribution and Pumping, Water Treatment and Transmission, Operations Support, Engineering and Construction and Planning, Figure 3.3 provides an overview of the water system. MWRA's system, in turn, feeds another 6,400 miles of locally owned water distribution pipes. Additional information on MWRA's structure, administration and staffing can be found on the MWRA web site: **www.mwra.com**.

Since 1984, issues at the forefront of MWRA's concern have changed over time:

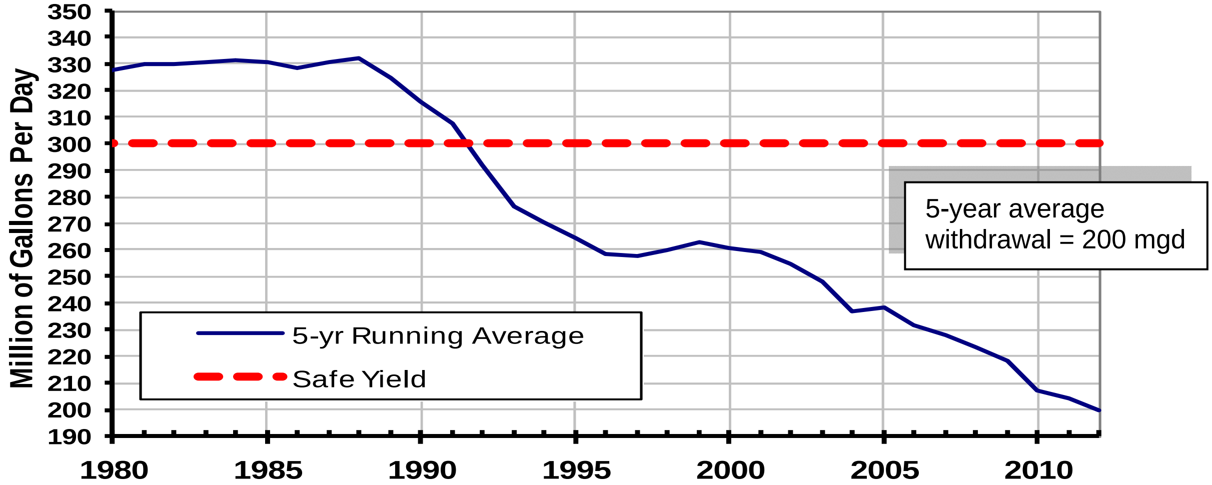
Supply

Following the construction of Quabbin Reservoir in the 30's, there was a continued expansion of the MWRA system driven both by the availability of the new supply and, in some cases, failure or inadequacy of local sources of water in some communities. Along with the growth in demand, the physical expansion of the system also continued and the 1970's saw the completion of the "Y"-shaped Metropolitan tunnel system (the City Tunnel, City Tunnel Extension to the north and the Dorchester Tunnel to the south). Demand had continued upward to a peak average daily demand of 342 mgd in 1980; beyond the safe yield of the sources. The drought of the 1960's had shown the potential vulnerability of the system as the level of water in Quabbin dropped to 45% full in 1967. Thus, the high demand and potential need for additional supply sources was one of the over-arching water supply issues as MWRA was created in 1984.

Demand

As a result of these demand pressures, MWRA launched its Long-Range Water Supply Program in 1987 with 30 different recommendations and programs and an investment of tens of millions of dollars. These initiatives were designed to reduce water use and water losses throughout the MWRA service area and to prevent additional demands due to loss of local sources to contamination. As shown in Figure 3-2 below, demand has steadily decreased from the 1980 high of 342 mgd to approximately 195 mgd in 2011. Total withdrawals increased slightly in 2012 to 200 mgd, however, the five-year running average continued to decline in 2012 to 200 mgd. Chapter 4 contains additional information on historical, current and future demand trends.

Figure 3-2: Total Reservoir Withdrawals -- Five Year Running Average 1980 to 2012



Water Quality

The focus then turned to the continued long-term protection of the sources and the modernization of the water supply system in compliance with new federal laws. In the early 1990's, MWRA established a 10 year $1.7 billion Integrated Water Supply Improvement Program. This program was designed to improve the reliability and quality of MWRA water and to meet the stringent requirements of the federal safe Drinking Water Act[1]. The Program included watershed protection, construction of new water treatment facilities, a new water transmission tunnel, covered storage facilities and distribution pipelines improvements. The capstone project, completed in 2005, was the John J. Carroll Water Treatment Plant that treats drinking water for the majority of MWRA customers, residents and businesses in Metro West and Metro Boston communities. The Plant uses ozone as a primary disinfectant and chloramines for residual disinfection, allowing MWRA to meet current and tougher future state and federal water quality standards. MWRA is currently moving forward with the addition of an ultraviolet light disinfection treatment process as a secondary primary disinfection process in order to meet the Long Term 2 Enhanced Surface Water Treatment Rule. In addition, as an unfiltered supply, source water quality and watershed protection are key factors to maintaining that status. DCR (formerly MDC) has implemented aggressive efforts to "control the watershed" through use of the State's Watershed Protection Act but also through the identification of critical lands and by taking action to prevent adverse development of those lands by use of fee simple purchases when necessary, or more commonly through purchase of conservation restrictions. These protections help retain MWRA's "unfiltered" status but also provide protection against many potential "emerging" contaminants which mostly impact water systems with significant upstream pollutant sources. Chapter 5 contains additional source water quality information and Chapters 6, 7 and 8 provide information on Water Treatment and Facilities, and the Transmission and Metropolitan Distribution systems.

[1] The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells. (SDWA does not regulate private wells which serve fewer than 25 individuals.)

Efficiency

As new facilities have come on line, MWRA has also made significant efficiency improvements in day to day operations. The fact that water flows to the east by gravity is of course a major advantage over many large systems. MWRA has continued many of the hydropower facilities put in place in earlier decades and has looked for opportunities to increase the use of hydropower and other renewable sources at new locations (See Chapter 10). With new facilities there has also been an increase in automation. New control and operating systems have allowed MWRA flexibility in staffing to meet CEB goals and have improved operational response times to emergency or anomalous system conditions.

Security and Redundancy

Since the events of September 11, 2001, MWRA, as all utilities, has returned to a focus on security and redundancy. As Chapters 7 and 8 explain, identification and elimination of “single points of failure” was a major topic in the 2006 Water System Master Plan and work has been completed or is ongoing for remaining distribution system redundancy projects. The 17.6 mile MetroWest Water Supply Tunnel was completed in 2003 and other major transmission system redundancy projects have moved forward into concept planning and design since 2006 as well. The transmission system coupling failure in May 2010 emphasized the need to continue to move forward with redundancy improvements and the need for continued maintenance of stand-by facilities to ensure a seamless transition to alternative or back-up systems as necessary (see Chapter 7 for further information). Vulnerability assessments of the system have been conducted and physical “hardening” of facilities continues. Much of this work has been accomplished in incremental phases as projects are designed and constructed.

3.3 Water Infrastructure Replacement Asset Value

MWRA water infrastructure is a network of reservoirs, facilities, structures, tunnels, and pipelines. In preparation of the 2006 Master Plans, staff developed replacement asset values for the water and wastewater systems using MWRA specific appraisal data and actual MWRA project cost information. For the 2013 Master Plan, the 2006 replacement asset value analysis was reused (in 2006 dollars) with only minor revisions for new facilities completed and on-line subsequent to the 2006 Master Plan. In 2006 staff estimated MWRA’s water infrastructure had a replacement asset value of approximately $6.3 billion. As shown in Table 3-1 and graphically in Figure 3-4, minor revisions were made to most categories of assets with the most significant change due to the completion of a number of pipeline projects since 2006 which increased the Pipelines/Valves category by $104 million. The Blue Hills Covered Storage Facility was also added to the Storage category. Overall, the current water system asset value replace amount is now estimated at approximately $6.5 billion. These values were used where appropriate to help develop reinvestment needs.

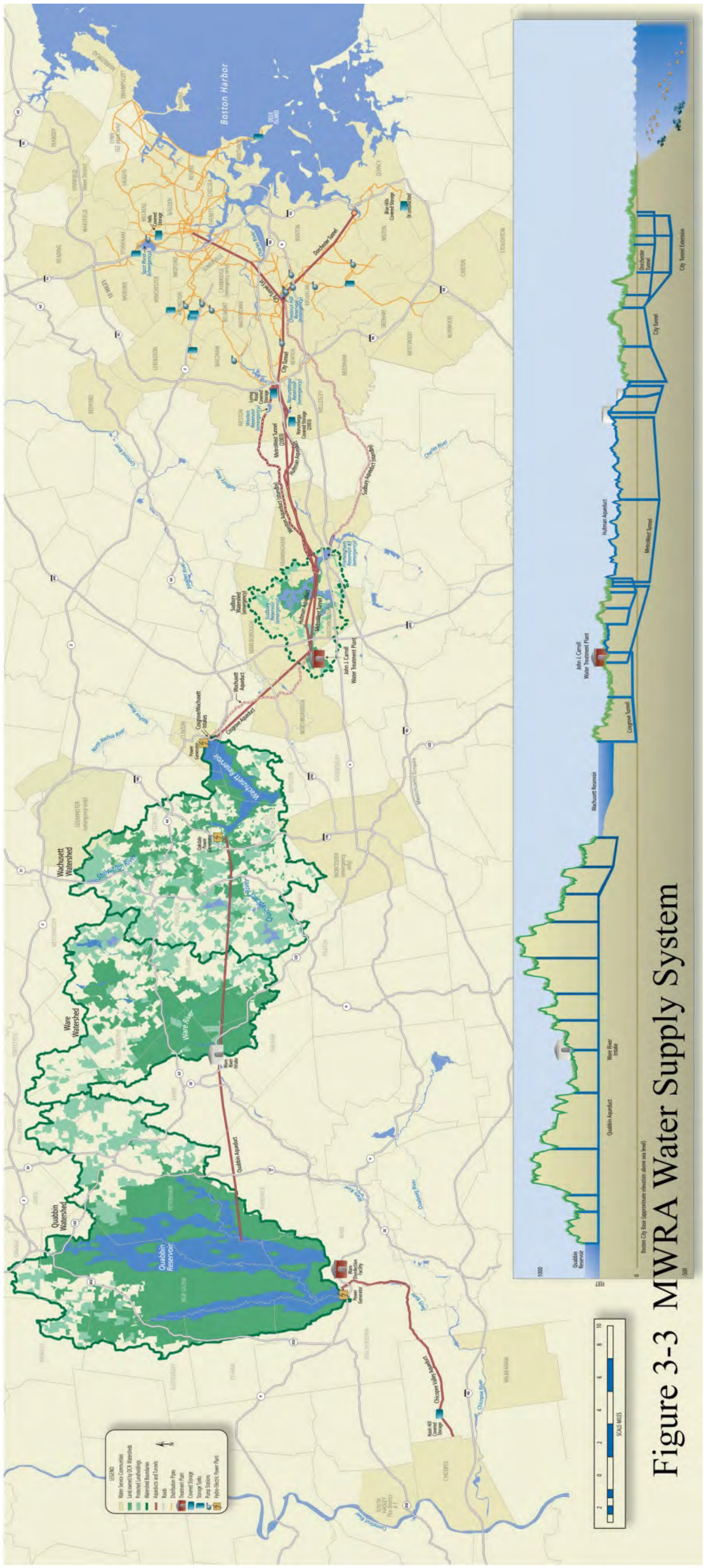
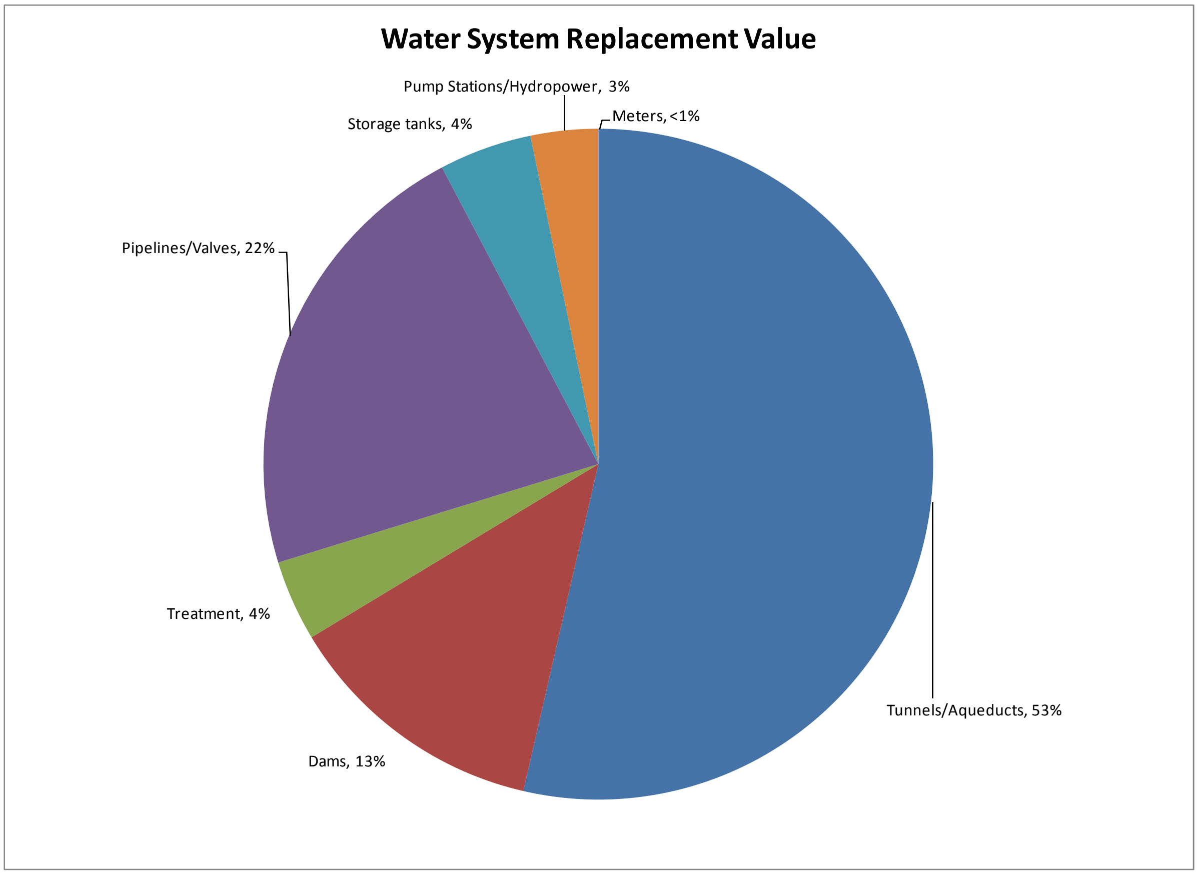


Figure 3-3 MWRA Water Supply System

Table 3-1

Water Infrastructure Replacement Value		
Asset Class	**Replacement Asset Value**	**% of Total**
Tunnels/Aqueducts	$3,474 million	53%
Dams	$828 million	13%
Treatment	$252 million	4%
Pipelines/Valves	$1,427 million	22%
Storage tanks	$290 million	4%
Pump Stations/Hydropower	$211 million	3%
Meters	$25 million	<1%

Figure 3-4



3.4 The Future Years

Completing major redundancy work will remain an agency priority for a number of years given the complexity of design, engineering and community issues to be resolved. And, as key redundant assets come on-line, it will be important to plan ahead for their use. While they will be available for day to day or emergency use, depending upon the asset, they will likely be primary water system facilities while other assets (tunnels, valves, pipelines etc.) are taken out of use, inspected and rehabilitated as necessary. It is important that planning for such transitions and the need to potentially access or replace valves in order to transition to new redundant facilities be addressed.

In addition, MWRA will also continue to monitor the physical condition of all water supply infrastructure from tunnels, dams, pump stations, storage facilities to valves, meters and other mechanical and electrical equipment to ensure that assets are rehabilitated or replaced in a timely manner.

Continued tracking of federal and state regulatory issues and requirements will also allow MWRA to be appropriately positioned to address new requirements or to take advantage of opportunities. This may include opportunities for further system expansion as environmental concerns are raised relative to local source withdrawals in the headwaters of area streams and rivers. Decreases in MWRA demands may allow additional communities to join the water system over the next decades. It will be important to continue to consider such possibilities as new infrastructure is planned, designed and built.

MWRA must proceed with these improvements while balancing the parallel goal of limiting rate increases to the customer communities to the extent feasible. The need to achieve and maintain a balance between these two goals is a critical issue facing MWRA today and into the future. In addition, MWRA must, like utilities across the country, deal with an aging workforce and the need to ensure knowledge transfer throughout the agency. MWRA remains optimistic that through smart planning, continued maintenance and upgrades of its facilities, controlling costs, and working as a partner to our service area constituencies that the Authority will successfully face and meet the challenges over the next 40 years to 2053.

4 Supply and Demand

Supply and demand characteristics of the MWRA system are documented in a series of annual staff summaries (most recently January 2013) and two major reports presented to the Board, *MWRA Water System Supply and Demand* (May 2002) and *Long Range Water Supply Planning Topics for Consideration II* (May 2006).

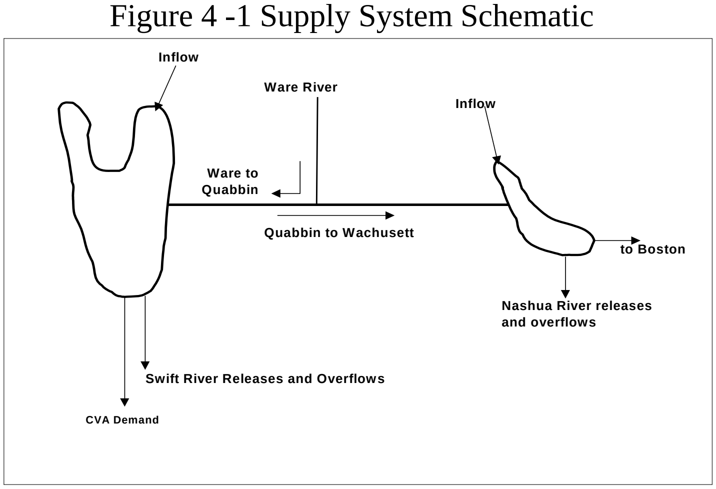
Water demand has dropped from a peak of approximately 340 million gallons per day in 1980, to approximately 200 mgd in 2012 compared to a safe yield of 300 mgd. Despite increases in population and employment within the service area, and the addition of six communities since 1993, both base demand (primarily indoor demand) and seasonal demand continue to decrease. A summary of key findings follows a brief introduction to the MWRA system to put the supply and capacity discussion in context.

4.1 Overview of the Water Supply System

The principal components of the MWRA system consist of Quabbin and Wachusett Reservoirs, the Ware River intake, the deep rock tunnels which deliver water by gravity eastwards and about 284 miles of pipe that distribute water to MWRA communities. The Quabbin Reservoir contributes about 53% of the total system yield, the Wachusett about 34%, and the Ware, 13% of total system safe yield. The MWRA reservoir system is operated with the primary objectives of ensuring high quality and adequate water supply and maintaining required minimum releases to the Swift, Nashua and Ware Rivers. Another operational objective includes maintaining an adequate flood protection buffer particularly during the spring melt and hurricane seasons. A third objective is to generate hydropower, which is currently generated at two locations within the source reservoir system (Oakdale at the outlet of the Quabbin Aqueduct, and the Cosgrove Intake) and a third location within the distribution system (Loring Road Covered Storage Facility).

Water can flow into each reservoir from inflows or transfers (Figure 4-1). Flow out of the reservoirs is made up of withdrawals for water supply, required or other planned releases, and overflows when the reservoir is full. Releases are mostly controlled (i.e. result of human decision) but they can also be uncontrolled (i.e. when the reservoir fills and overflows).

Figure 4 -1 Supply System Schematic



Quabbin Reservoir

Water is discharged from the Quabbin Reservoir primarily from the Quabbin Aqueduct where it ultimately discharges into the Wachusett Reservoir, after first passing through a hydropower turbine at Oakdale Station. Quabbin transfers constitute more than half of the average annual inflow to Wachusett Reservoir. Releases from Quabbin also occur through the Chicopee Valley Aqueduct to supply water to three communities west of Quabbin.

Additional outflow from Quabbin includes discharges to the Swift River at the Winsor Dam, pursuant to Chapter 321 of the 1927 Acts of Massachusetts and the 1929 War Department Requirement. The 1927 Acts of Massachusetts requires that sufficient water must be discharged from Quabbin Reservoir to provide at least 20 mgd in the Swift River at Bondsville located 5 miles downstream of Winsor Dam. No matter how low precipitation levels are, MWRA provides at least 20 mgd in the Swift. The 1929 War Department Requirement also requires additional releases. From June 1 to November 30, streamflows on the Connecticut River at Montague govern the required releases to the Swift River. When the daily average flows in the Connecticut River at Montague are less than the 4900 cfs and 4650 cfs, the releases from Quabbin must equal 45 mgd and 70 mgd, respectively. Thus during dryer periods, the required releases actually increase. Between December-May, and when flows in the Connecticut River at Montague are above 4900 cfs, the minimum flow release of 20 mgd at Bondsville governs.

Design is currently underway for 5,000 linear feet of new pipeline which will convey 6 mgd of cold, well oxygenated, hypolimnetic water from Quabbin Reservoir to the downstream McLaughlin State Trout Hatchery. This will provide a consistent and reliable source of high quality water to the hatchery as well as supplement flows to the Swift River. The project will also include a hydro-electric turbine that will capture some of the hydraulic energy contained in the pipeline as the water is conveyed to the hatchery. The power generated will be used at the Ware Disinfection Facility and surplus power will be sold to the grid. The hydro portion of this work is funded under the Alternative Energy Initiatives project.

Wachusett Reservoir

Wachusett Reservoir is operated to meet three primary objectives.

The first objective is to maintain Wachusett's elevation in a narrow operating band. The range of elevations was established because it provides adequate supply to meet customer demands, minimizes shoreline erosion, provides adequate free board to minimize spillway activations (and the possibility of downstream flooding), and improves water quality by submerging gull roosting areas near the intake.

The second objective is to maintain acceptable water quality at the intake. MWRA has historically maintained water quality by mixing Wachusett water with higher quality Quabbin water, which is transferred through the Quabbin Aqueduct. Transfers from

Quabbin to Wachusett are beneficial any time of the year since they lower, by dilution, the concentration of reactive organic matter considered a precursor to disinfection byproducts. Through reservoir modeling and testing, MWRA has also observed the benefit of transferring water between reservoirs particularly between May and October. During this time of the year the reservoir's thermocline has developed which allows the colder water transferred from Quabbin to move as an *interflow* from the aqueduct's point of discharge to the Cosgrove Intake, providing a more rapid and stronger effect. Having the higher quality water at the intake is particularly important during this period due to the relationship between warmer temperatures and disinfection processes. Testing shows that sustained flow rates of 250 to 300 mgd appear to be necessary to create this desired interflow regime. When Wachusett watershed yields are sufficient to maintain reservoir elevations within the normal operating range, and transfers of additional water for water quality purposes are made, higher levels of releases from valves at the Wachusett Dam may and do occur. With decreased demands for water supply in the MetroBoston and MetroWest region, it has become increasing necessary to release more flows to the Nashua River (and occasionally to the Sudbury Reservoir and Sudbury River) to allow for sufficient transfers of Quabbin water to ensure a high quality water supply, especially in wetter years with higher inflows from the Wachusett watershed. In prior years, higher demand for water supply meant higher quantities of Quabbin transfers were needed to simply keep up with the demand.

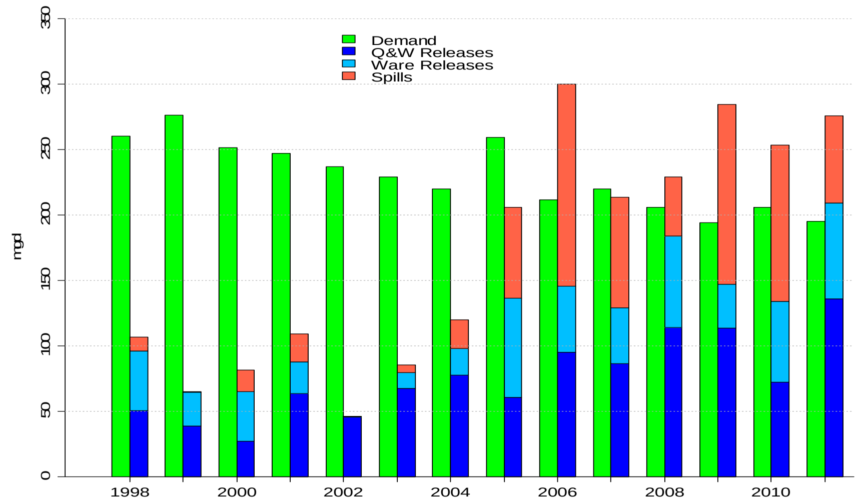
The third objective is to meet the minimum release requirement. The MWRA discharges water to the Nashua River consistent with *Chapter 488 of the Acts of 1895,* which requires that not less than 12 million gallons per week must be discharged into the South Branch of the Nashua River. As part of larger the discussion to add additional communities to the MWRA service area, consideration is being given to potentially increasing minimum releases during non-drought periods.

Ware River

The MWRA can increase system safe yield through transfers from the Ware River watershed to Quabbin Reservoir. Ware River transfers are limited to a period when river flows exceed 85 mgd and are subject to the following conditions: no diversion of Ware River flows are allowed from June 15 to October 15. Diversions from June 1 to June 15 and from October 15 to November 30 must have prior permission from the DEP Division of Water Supply.

Figure 4-2, below compares the amount of water withdrawn to supply customer demand to the total amount of water spilled and released to the Swift River from Quabbin Reservoir, water spilled or released to the Nashua River from Wachusett Reservoir, water released from Wachusett Reservoir to the Sudbury River through the Wachusett Aqueduct, and Ware River water, which could have been transferred to Quabbin but was not due to lowered demands. With reduced demands, MWRA's annual average releases and spills from the reservoir system have exceeded the amount of water withdrawn for water supply purposes five times in the last 14 years: 2006, 2008, 2009, 2010, and 2011.

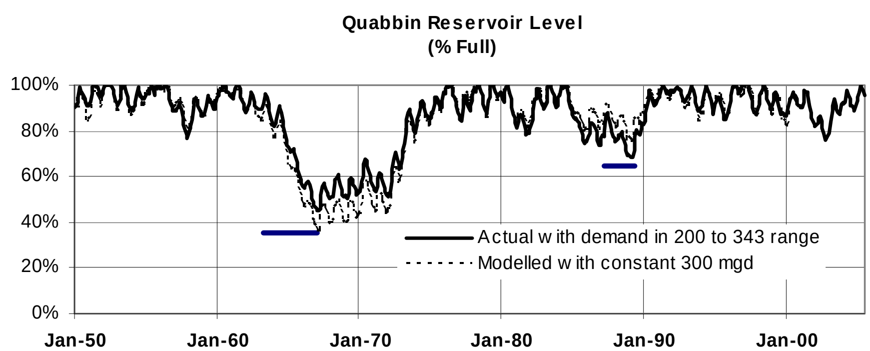
Figure 4-2 Spills, Releases and Demands



4.2 System Capacity

The safe yield is the quantity of water that can be reliably supplied over a period that includes a critical drought. The safe yield of the Wachusett-Ware-Quabbin system has been described as around 300 million gallons per day since the design of the Wachusett Aqueduct in 1895. Since then, many studies have been completed – in 1922, 1950 and several during the 1980's and 1990's – which validate that 300 mgd is a conservative estimate of safe yield. The figure below shows the modeled performance of the system during a drought as severe as the 1960s and the 1989 drought, with modeled demands of 300 mgd as well as actual historical demand. Even in a drought as severe as the multi-year drought of the 1960's, Quabbin storage levels would only drop to around 40 percent with demands as high as 300 mgd.

Figure 4-3 Quabbin Reservoir Levels Showing Performance During Drought



The amount of water a system can supply can be enhanced if a drought management plan is used to curtail demand. MWRA developed a Drought Management Plan in 1989 that has since been incorporated into the state plan. The objective of the plan is to conserve water through implementing demand reduction measures, allowing the system to withstand a more severe drought without jeopardizing reliability. Drought response actions are triggered by seasonal levels of Quabbin Reservoir. Table 4-1 presents the stages of this plan.

Table 4-1
MWRA Drought Management Stages

Stage	**Trigger** Range (Quabbin % Full)	**Target Water Use Reduction**
Normal Operation	80-100	0
Below Normal	65-90	Previous year's use (Voluntary)
Drought Warning	50-75	5% (Voluntary)
Drought Emergency		(Mandatory Restrictions)
Stage 1	38-60	10%
Stage 2	25-38	15%
Stage 3	Below 25%	30%

At current demands, or demands up to 240 mgd, no drought actions would be triggered even in a drought as severe as the 1960's.

4.3 Potential Impacts of Climate Change

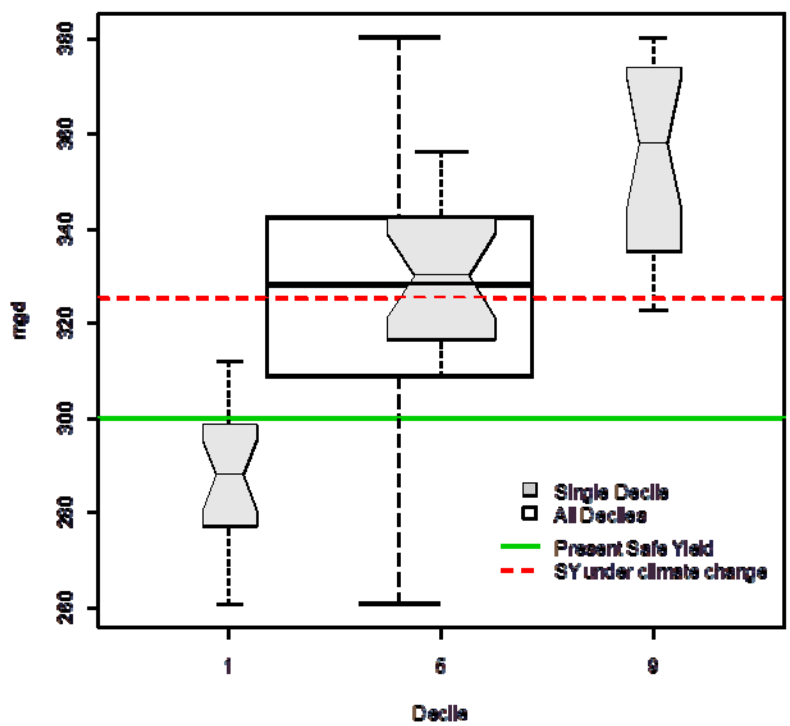
MWRA staff have undertaken a series of efforts to evaluate the potential impacts of climate change on the MWRA water system, working with researchers for several universities and research institutions, including several studies funded by the Water Research Foundation. These cooperative efforts have leveraged MWRA staff knowledge of our system and our sophisticated reservoir modeling tools to allow MWRA to participate in these regional or national studies.

In the New England region, most climate change models and scenarios show both an anticipated increase in temperature and an increase in precipitation. Many of the models also show changes in the patterns of precipitation, in particular, periods of both dryer and wetter conditions, and potentially more extreme conditions. (Referred to in the popular literature as "wetter wets and dryer drys" and more intense storms.)

Working with climate specialists from the National Center for Atmospheric Research (NCAR) a probabilistic estimate of the impact of climate change on Safe yield was done. This work is described in detail in a 2011 Water Research Foundation Report authored by David Yates and Kathleen Miller titled "Climate Change in Water Utility Planning: Decision Analytic Approaches." At the heart of the probabilistic approach is the strategy of using all the results of available General Circulation Models (GCMs) to derive regional probability distributions of the likely increases in temperature and precipitation. Climate ensembles are then derived using statistical techniques at the 10th percentile, median, and 90th percentile (1st, 5th and 9th deciles) of these distributions, which are in turn used to estimate Safe Yield. This contrasts with earlier efforts which looked at only a single point estimate of a single climate model and greenhouse gas scenario. Along with the probabilistic modeling, more geographically detailed rainfall projections were used, based on actual rainfall data adjusted for the climate projections. In previous modeling, only generalized regional rainfall data was available, and at only monthly time steps. The most recent work included localized rainfall and weekly time steps. The current approach provides more robust and descriptive results, but these are generally in line with the several previous modeling studies, which indicated an expected increase in Safe Yield.

Figure 4-4 summarizes the outcome of this study, and it shows an expected overall estimate of 324 mgd, representing a modest increase of 8% over current yield under the modest emissions scenario that was considered in the study. In well over 90 percent of the simulations, yields were up, in some cases substantially. In a small number of cases, simulations indicated that yields could decrease. These results have recently been duplicated over a wider range of climate change scenarios in on-going work by a research team at U-Mass Amherst.

Figure 4-4 – Potential Increase in Safe Yield with Climate Change



The potential increase in Safe Yield is largely due the large over-the-year storage of Quabbin Reservoir. The large storage volume of Quabbin allows it to capture the increased precipitation, and more inflow from more intense storms, making it available for use during dry periods. In other parts of the country, and elsewhere in Massachusetts, systems without very large reservoirs will find that their reservoirs overfill (and overflow) during wet periods, and do not have enough storage to get through dry periods, reducing their safe yields. The partially-supplied and self-supplied communities on the periphery of our service area that do not have over-the-year storage will be vulnerable and are likely to turn to the MWRA for emergency supplies. Some of the redundancy planning projects described in the master plan can therefore be thought to have dual uses. In addition to providing redundancy, they also increase transmission capacity which may be needed to supply neighboring communities as their supplies become less reliable.

Potential impacts of climate change on water demand are described below in Section 4-4, and those of the potential impacts of sea level rise are described in other sections of the Master Plan.

4.4 Current System Demand

System water demand on the MDC system increased steadily during the 60's, 70's and 80's. In 1986, rather than pursue options for increasing supply, MWRA's Board of Directors opted to pursue a range of demand management strategies. Following this commitment, MWRA launched its Long-Range Water Supply Program in 1987 with 30 different recommendations and programs requiring an investment of tens of millions of dollars over the next decade. The demand management and supply protection programs were designed to reduce water use and water losses throughout the MWRA service area and prevent new demands due to local source contamination.

MWRA system demand now averages approximately 200 mgd (5-year average 2008-2012), a decline of approximately 142 mgd from the 1980 peak of 342 mgd. Between 1980 and 2010, the population within the original MWRA service area grew by about 163,000, and six new communities were added to the service area with a population of 135,000. Within the same time period (1980 to 2010), water demand decreased by approximately 130 million gallons per day. MWRA's aggressive water conservation efforts, including local leak detection and repair programs, yielded significant gains early on, with a 20 percent drop in five years. The new plumbing code, more efficient appliances, the shift in the commercial base from water-intensive manufacturing to less intensive users, good system management, and improved metering all likely contributed to lower demand. Significant water and sewer rate increases also played a part in focusing attention on water use efficiency and thus reducing water use in member communities. The recent economic slowdown likely accelerated water use reductions. While not as dramatic as the reduction in water demand in the MWRA service area, decreased residential water demand is also occurring in many utilities across the country, due to many of the same factors.

Over time, reductions have come in both base use, defined as water use from November to March, and outdoor use (or seasonal use), defined as the increase over the base demand during the irrigation season of May to September. Reductions in base use in fully-supplied communities continue to show a decrease of approximately 3 mgd per year, as shown by the dotted sloping line in Figure 4-6[1]. These reductions of

[1] Certain analyses can only be done on fully-supplied communities where MWRA has information on their total use available from MWRA's revenue meters. MWRA receives data on monthly total use for partially-supplied communities, but not until they provide that data to DEP in their Annual Statistical Reports in March. Fully supplied communities represent almost 90% of the total annual demand.

approximately 1.8% annually are generally due to increases in the efficiency of water use in homes and businesses as water-saving technologies continued to increase market share

Figure 4-5 Total Reservoir Withdrawals-Five Year Running Average 1980-2011

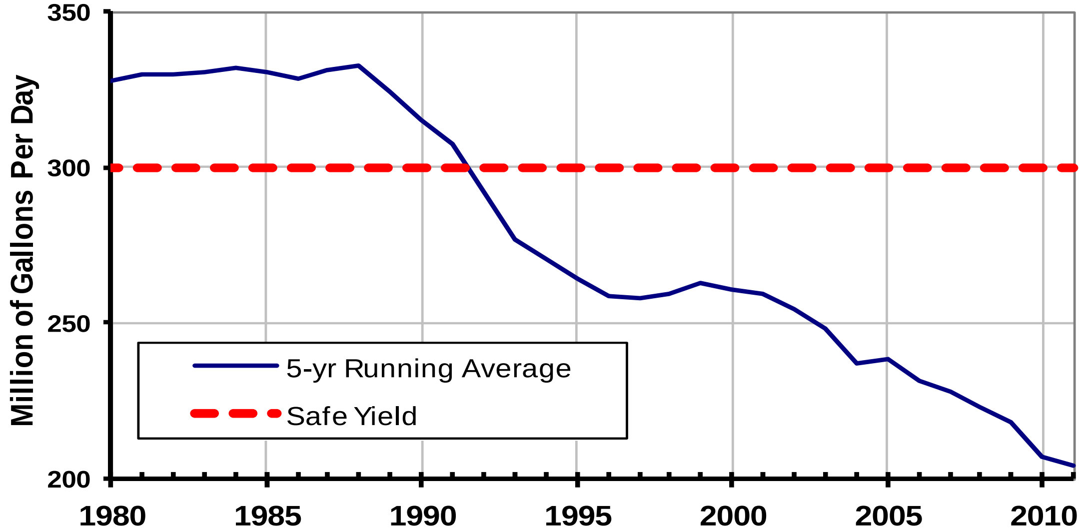
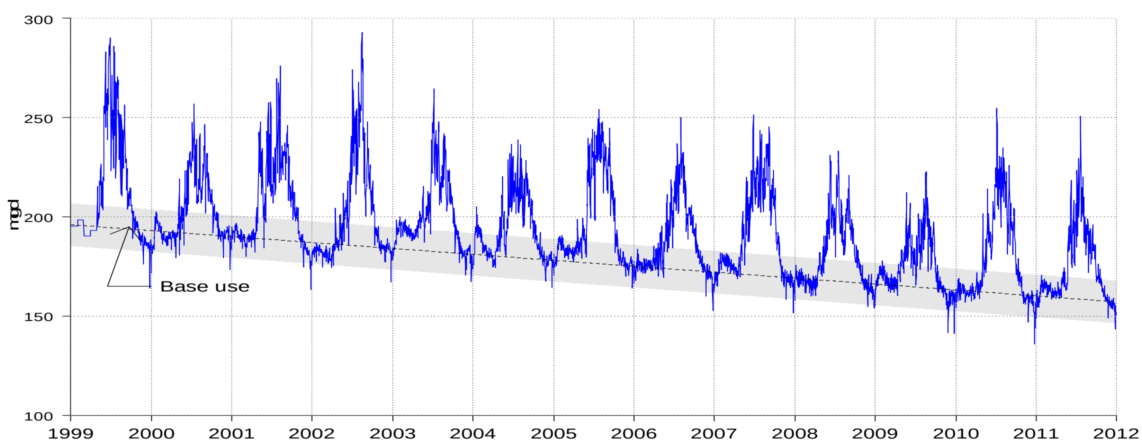


Figure 4-6 Fully-Supplied Communities Daily Demand 1999-2011

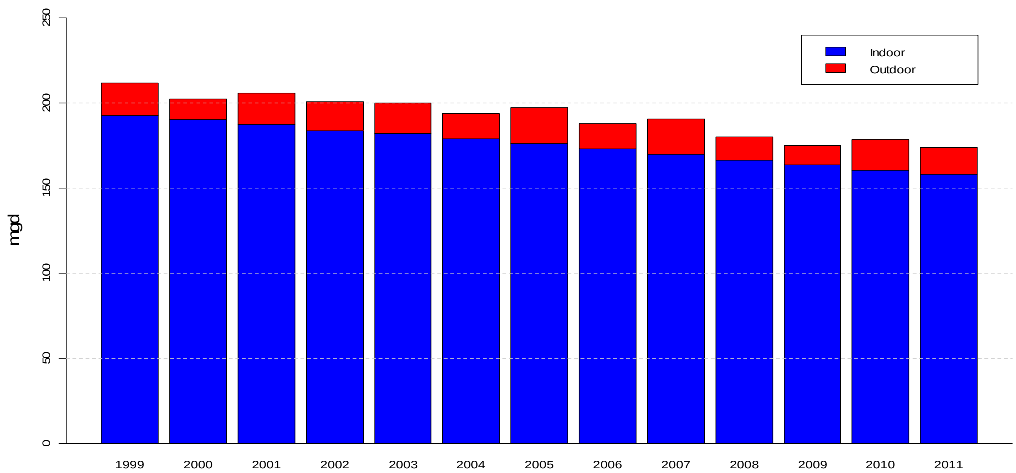


and consumers reacted to price increases, as well as reduced pipeline leaks. These reductions seem likely to continue for some time. This trend is similar to New York City's decline in base demand of 1.6% annually over the last 5 years.

Seasonal water use is more variable and driven in large part by weather during the irrigation season. Factors influencing seasonal use include the total irrigation season precipitation, the number of dry days between rainfall events, temperature, and the total amount of sunshine. Over time, water price also influences seasonal use. During the past

13 years, seasonal use in the fully-supplied communities has varied from a low of 10 mgd (6% of total use) in 2009 to 21 mgd (11%) in 2005, with an average of approximately 16 mgd (8%).

Figure 4-7: Fully-Supplied Communities' Annual Base and Seasonal Demand



Annually, public water suppliers across Massachusetts file Annual Statistical Reports (ASRs) with DEP. The reports provide data on the components of water demand in the MWRA service area. As seen in the Table 4-2, residential water use represents almost fifty-eight percent of total water use in the service area. Based on the reported data in the ASRs, the residential gallons per capita per day (RGPCD) in the MWRA water service area in 2010 was 56, which is similar recent years. The state performance standard for residential consumption is 65 RGPCD.

Table 4-2

Water Use in the MWRA Service Area (2010)

Type of Use	Percent of Total (available for distribution)
Residential	57.8%
Commercial	15.5%
Industrial	2.5%
Municipal	8.7%
Agricultural	0.1%
Other	0.2%
Unaccounted for Water[2]	15.2%

In examining demand, it is helpful to look separately at different classes of customers. MWRA serves several categories of communities: fully supplied communities which take all of their water from MWRA; partially supplied communities which normally supply a

[2] Unaccounted for water includes losses due to leaks, but also unmetered uses and under registration of use from older meters.

portion of their demand with locally owned and operated surface and groundwater sources; emergency-only communities, and certain miscellaneous users.

Fully Supplied Communities

There are 22 core MWRA water and sewer communities that are fully supplied users that take all of their water from MWRA. Fully supplied communities also include the three Chicopee Valley Aqueduct (CVA) communities, and seven communities in the metropolitan area that are part of the MWRA water system, but not the sewer system. Average annual water demand of fully supplied communities in 2012 was 173.4 mgd.

Partially Supplied Communities

There are fourteen communities served by MWRA that typically use a combination of local sources and MWRA water to meet their demand. In 2009, 11.8 mgd of demand in the partially supplied MWRA communities was met by MWRA, whereas 35.6 mgd was met by local sources (Table 4-3). MWRA's obligations to its partially supplied communities, though, are to provide the communities additional water if local sources are not sufficient. Many of the local supplies are small and thus are subject to more significant variations in available water. Shorter-term periods of dry weather that would not have significant adverse effects on the Quabbin/Wachusett/Ware system may reduce available supply at the local level resulting in water use restrictions or the need to supplement local supplies with additional water from the MWRA. MWRA’s drought plans assume increased use by partially supplied communities during a drought.

Table 4-3
MWRA Partially Supplied Communities

Community	**Local Sources (mgd)**	**MWRA (mgd)**
Canton	0	2.208
DWWD	3.8	0.001
Lynn	10	0.1676
Marlborough	2.189	2.351
Needham	2.969	0.261
Northborough	0.03	0.781
Peabody	5.04	0.386
Stoughton	1.27	0.551
Wakefield	2.27	1.494
Wellesley	1.7	1.022
Wilmington	1.937	0.099
Winchester	1.02	0.823
Woburn	3.39	1.685
Total	**35.615**	**11.8296**

Emergency Communities

The communities of Leominster, Worcester and Cambridge are also eligible to receive MWRA water; they use MWRA as an emergency back up and do not routinely purchase MWRA water. In 2012, these communities withdrew approximately 39 mgd from their local sources (which in the case of Worcester, include a sub-basin of the Wachusett Reservoir), and less than one mgd collectively from MWRA. MWRA's drought plans also assume increased demand from these users during a drought.

Miscellaneous Uses and Obligations

Worcester's Pine Hill Reservoir is in the Quinepoxet sub-basin of the Wachusett watershed. Pursuant to Chapter 699 of the Acts of 1949, Worcester has first rights to the flows in the Quinepoxet. Therefore, Worcester's water supply indirectly exerts a demand on the MWRA/MDC reservoir system and affects system yield. (Essentially what they do not take from their source, runs down into the Wachusett Reservoir.) Clinton is also allowed to withdraw up to 800 million gallons per year of raw water from the Wachusett Reservoir from its own intake at Wachusett Reservoir at no charge. Clinton's current demand is approximately 2 mgd. MWRA also supplies several facilities including the Lynn General Electric Plant and the Westborough State Hospital.

Emergency Demands from Neighboring Communities

MWRA policies allow for supplying water to non-member communities under emergency conditions. These could be a loss of supply due to contamination or facility failure, major main breaks, or reduction in supply due to drought or overuse due to growth. MWRA plans assume some small amount of emergency demand, but our policies encourage communities to resolve local supply problems or move toward join the MWRA system long term if local supplies are inadequate.

4.5 Projected System Demand in 2035

Projecting the demand on the MWRA system into the future must acknowledge two competing trends: continuing increases in efficiency in the home and workplace and an increase in population and employment within the service area. Any projections must also include assumptions about the potential for partially supplied customers to turn toward the MWRA for an increased portion of their supply periodically or long term, and the assumptions about the potential for new communities to join the MWRA system. How all the assumptions are worked together can provide varying degrees of conservatism in the planning projections. The master plan projections are conservative and thus protective of existing customers:

- They assume current levels of conservation and efficiency among existing users;
- They assume new residential use will be slightly less efficient than the current average; and
- They provide for an assumed level of increased use by partial users.

Because they are conservative, plans for system expansion can be evaluated without jeopardizing the reliable supply of current and future users within the service area.

Existing Service Area

Population projections prepared by planning agencies, primarily the Office of Transportation Planning in the Massachusetts Department of Transportation and the Metropolitan Area Planning Council, were used as the starting point for projecting future water demand.

In February, 2011, the MAPC adopted population projections for 2035 for 101 communities; the population projects represent the official demographic scenario for the region. The population projections include 46 communities of the 50 communities that are part of the MWRA water service area. Projections reflect totals for population and employment issued by the Massachusetts Department of Transportation (MDOT) Office of Transportation Planning and also incorporate data from MAPC's development data base for residential and commercial developments recently completed, constructed, or planned. Communities collaborated and reviewed the projections, which underwent public review prior to finalization. Similarly, the MDOT also developed population projections for the CVA area communities, which were reviewed by the Pioneer Valley Regional Planning Commission prior to their adoption as the official demographic scenario.

The MDOT projections for 2035 were developed prior to the availability of the US. Census 2010 numbers. MAPC projections for 2035 will be updated at some time in the future reflect the 2010 census data.

Population growth between 2010 and 2035 for water communities typically served by MWRA (which does not include emergency-only communities of Worcester, Leominster, and Cambridge) is projected by MAPC to increase by approximately 200,000, or 9.4%. More than half of this regional population growth is projected by MAPC to occur in Boston.

Conservatively assuming a residential consumption rate of 65 gallons per capita per day (the state performance standard), the total increase in residential water demand throughout the MWRA service system would be approximately 13 mgd if it is assumed that new population growth in MWRA's communities, both partially and fully served, would be met by MWRA, not local sources. An assumption of 65 RGPCD is consistent with the Massachusetts Water Resources Commission water needs forecasting methodology. Since the projections assume an RGPCD of 65, rather than the actual 2010 RGPCD of 56 for the MWRA service area in 2010, the 2035 projection of an additional 13 mgd in residential demand is considered conservative. It is also particularly conservative given that Boston's population growth, as projected by MAPC, comprises approximately half of the total system growth, and Boston's residential per capita consumption has ranged between 42-51 RGPCD over a number of years.

Attachment 1, at the end of this chapter, presents population projections by community, and by MWRA water pressure zone/service area. Note that some communities lie in more than one service area. In these cases, the community was generally grouped into the water pressure zone where the greatest majority of its land area lay. Precisely where in the community, growth will occur is beyond the scope of this analysis, and would only lend false precision.

MDOT also developed employment projections which were similarly reviewed by the MAPC and PVRPC; based on employment data for 2010 and MDOT and MAPC adopted employment forecasts through 2035, the MWRA water service area is projected to add 119,984 new jobs by 2035, or 8.7%. To project water use associated with increased employment, the Water Resources Commission Water Needs Forecast methodology was used. This methodology multiplies the baseline non-residential average daily demand (ADD) by the percent change in employment to derive the new water demand due to employment growth. For the MWRA fully and partially supplied communities, the non-residential demand is 57.4 mgd. Based on MDOT employment projections adopted by the Regional Planning agencies, 8.7% employment growth between 2010 and 2035 is projected, resulting in an increase of 5 mgd in non-residential demand, or 45 gallons per each new employee. The WRC's methodology is arguably conservative, as the non-residential demand includes not only commercial, industrial, agricultural and other uses, but also includes all municipal water uses. Attachment 2 provides the community by community employment projections.

Projected new demand in each service area is summarized in Table 4-4. While the greatest growth, approximately 12 mgd, is projected in the Low Service Area, it should be noted that current use plus projected growth in demand in this service area is well below the historical demand.

In terms of total system demand, future population and employment growth is projected to be very modest – a total of approximately 18 mgd. Adding 18 mgd to the average annual demand of the MWRA water service area for the five preceding year's results in a demand estimate of 222 mgd in 2035, if it assumed that use of local sources remains roughly the same.

A factor in the overall demand on the MWRA system is the potential for changes in the use of local sources through either restrictions on use of local sources (e.g., communities in the Ipswich River Basin), decrease or loss of local sources , or potential development of new local sources (e.g. Framingham). While it is might be reasonable to assume that that there will be no substantial change in local sources, as the various increases and decreases balance out, a more conservative assumption is to provide cushion for partially supplied and emergency supplied communities to require additional water from MWRA.

Table 4-4
Existing MWRA Service Area
Projected Increase In Water Demand Due to Population and Employment Growth
2010-2035

PRESSURE ZONE	New Water Demand Residential (mgd)	New Water Demand Employment (mgd)	Total New Demand (mgd)
Intermediate High	0.16	0.03	0.19
Low Service	8.56	3.38	11.94
Northern High	1.19	0.19	1.38
Northern Intermediate High	0.65	0.11	0.66
Northern Extra High	0.33	0.23	0.56
Southern High –Norumbega	0.39	0.12	0.51
Southern High- Dorchester Tunnel	0.26	0.19	0.45
Southern Extra High	0.64	0.24	0.88
MetroWest	0.55	0.31	0.86
CVA	0.26	< 0.10	0.35
TOTAL	**12.99**	**4.9**	**17.77**

MWRA staff continue to examine the potential effects of both an increased environmental awareness in how local sources are operated (perhaps in the short term), and the possibility that climate change may decrease the reliable yield of some local sources as discussed above (over the longer term). While conceptually both result in a long term increase in demand on the MWRA system, no numerical analysis is possible at this point in time. Assuming approximately 25% of the demand in both the partially supplied and emergency-only communities now met by local sources were to be met by MWRA, this would equate to approximately 17 mgd.

Potential Effects of Climate Change on Demand

There is limited information on the potential effects of climate change on demand in a climatic region such as MWRA's; most existing work has been done in more arid regions. However, MWRA staff have examined some of the factors which currently drive seasonal demand (primarily outdoor uses) on the assumption that these will be the uses most affected. Seasonal demand represents only a small portion of MWRA demand – averaging about 8 percent. Warmer temperatures during the growing season tend to raise seasonal demand, particularly periods of consecutive days above 85^{o}. Precipitation during the growing season depresses demand, while periods of consecutive days without rain increase it. While climate models can provide average changes in rainfall and temperature on a monthly or weekly time step, this is not sufficient for a robust evaluation of seasonal demand changes. Overall, based on what information is available, it seems likely that the impact on demand is likely to be relatively small, on the order of a several percent increase. Given that base demand has been dropping by almost two percent per year, these current demand projections do not include an allowance for climate change. MWRA staff will continue to review this factor as better information on potential changes in climate become available.

Summary of Projections

Combining the existing five year average use of 204 mgd, with the 18 mgd growth from increased population and employment, and the conservative assumption of 17 mgd additional demand from partial users results in a total projected demand on the MWRA system of approximately 239 mgd. The safe yield of the MWRA supply system is approximately 300 mgd. This would still leave a comfortable margin of approximately 60 mgd between demand from the existing service area and safe yield.

Current demand within the service area	200 mgd
Growth due to increased population and employment	18 mgd
Potential increase in demand from partial user communities	17 mgd
TOTAL PROJECTED DEMAND IN 2035	**235 mgd**
Supply System Safe Yield	300 mgd
AVAILABLE MARGIN	**65 mgd**

Potential Service Area Expansion

In 2013, a number of communities not currently served by the MWRA water system are seriously considering MWRA water to supplement their local sources. They are in the process of undertaking appropriate studies. Collectively, their projected demand from MWRA is less than 10 mgd.

There are additional communities at MWRA's periphery that derive their local sources in river basins where there is extensive flow alteration. Local water supply withdrawals are one factor that contributes to extensive flow alteration.   A flow policy and regulatory scheme that may emerge from a Sustainable Water Management Initiative (SWMI) led by the Executive Office of Energy and Environmental Affairs may result in restrictions on expansion of water supply. In the long run, to accommodate growth, there may be more reliance on a regional water management approach that capitalizes on the ample capacity of MWRA's large storage reservoirs.

This is an area of evolving information and policy, and will continue to be evaluated by staff. It seems likely that some new communities will join the MWRA system, but the review of likely cases indicates that the demand will be small compared to the available margin between projected demand and supply.

Attachment 1

Table 4-3
MWRA Service Area Population Projections and Additional Water Demand

Service Area	Community	2010 Census	2035 Projection	2010-2035 Increase	Add. Water (gpd)
Intermediate High					
	Belmont	24,729	25,444		
	Watertown	31,915	33,641		
	TOTAL	**56,644**	**59,085**	**2,441**	**158,665**
Low Service					
	Boston	617,594	727,719		
	Cambridge	105,162	123,300		
	Chelsea	35,177	43,905		
	Everett	41,667	40,237		
	Malden	59,450	61,449		
	Somerville	75,754	88,045		
	TOTAL	934,804	1,084,655		
	TOTAL w/o Cambridge	**829,642**	**961,355**	**131,713**	**8,561,345**
Northern High					
	Lynn				
	Lynnfield	11,596	13,395		
	Marblehead	19,808	21,109		
	Medford	56,173	57,914		
	Melrose	26,983	28,596		
	Nahant	3,410	3,758		
	Peabody	51,251	53,376		
	Revere	51,775	57,167		
	Saugus	26,628	29,281		
	Swampscott	13,787	14,852		
	Winthrop	17,497	17,911		
	TOTAL	**278,908**	**297,359**	**18,451**	**1,199,315**
Northern Intermediate High					
	Reading	24,747	25,687		
	Wakefield	24,932	27,253		
	Wilmington	22,325	24,514		
	Woburn	38,120	40,335		
	Stoneham	21,437	23,716		
	TOTAL	**131,561**	**141,505**	**9,944**	**646,360**
Northern Extra High					
	Arlington	42,844	42,173		
	Bedford	13,320	14,373		
	Lexington	31,394	32,545		
	Winchester	21,374	22,475		
	Waltham	60,632	63,049		
	TOTAL	**169,564**	**174,615**	**5,051**	**328,315**
Southern High off of Norumbega Supply Lines					
	Newton	85,146	86,303		
	Needham	28,886	30,627		
	Weston	11,261	14,023		
	Wellesley	27,982	28,301		
	TOTAL	**153,275**	**159,254**	**5,979**	**388,635**
Southern High off of Dorchester Tunnel					
	Brookline	58,732	59,499		
	Quincy	92,271	95,563		
	TOTAL	**151,003**	**155,062**	**4,059**	**263,835**
Southern Extra High					
	Canton	21,561	23,056		
	Dedham	24,729	27,039		
	Norwood	28,602	29,728		
	Milton	27,003	27,000		
	Stoughton	26,962	29,927		
	Westwood	14,618	16,553		
	TOTAL	**143,475**	**153,303**	**9,828**	**638,820**
MetroWest					
	Framingham	68,318	71,288		
	Marlborough	38,449	40,756		
	Northborough	14,155	16,400		
	Southborough	9,767	10,686		
	TOTAL	**130,689**	**139,130**	**8,441**	**548,665**
CVA					
	Chicopee**	55,298	57,570		
	South Hadley**	14,000	14,644		
	Wilbraham**	14,219	15,267		
	TOTAL**	**83,517**	**87,481**	**3,964**	**257,660**
	TOTAL	**2,128,278**	**2,328,149**	**199,871**	**12,991,615**

Attachment 2

Table 4-4
MWRA Service Area Employment Projections and Additional Water Demand

Service Area	Community	2010 Total Employed	2035 Total Employed	2010-2035 Delta	Water Increase (gpd/cap) - 45
Intermediate High					
	Belmont	6,263	6,437		
	Watertown	18,334	19,072		
	TOTAL	**24,597**	**25,509**	**912**	**30,096**
Low Service					
	Boston	545,079	603,393		
	Chelsea	13,393	14,973		
	Everett	12,771	12,894		
	Malden	15,031	15,133		
	Somerville	20,435	35,564		
	TOTAL	**606,709**	**681,957**	**75,248**	**3,386,160**
Northern High					
	Lynn				
	Lynnfield	5,493	6,163		
	Marblehead	4,619	4,791		
	Medford	17,906	19,327		
	Melrose	6,273	6,468		
	Nahant	412	412		
	Peabody	23,028	23,231		
	Revere	8,873	10,031		
	Saugus	10,079	10,592		
	Swampscott	3,549	3,554		
	Winthrop	1,885	1,898		
	TOTAL	**82,117**	**86,467**	**4,350**	**195,750**
Northern Intemediate High					
	Reading*	6,417	6,649		
	Wakefield	14,091	14,054		
	Wilmington*	18,939	18,162		
	Woburn	38,887	41,498		
	Stoneham	7,757	8,252		
	TOTAL	**86,091**	**88,615**	**2,524**	**113,580**
Northern Extra High					
	Arlington	7,797	8,035		
	Bedford	21,561	22,697		
	Lexington	19,287	21,696		
	Winchester	8,409	8,805		
	Waltham	54,248	55,241		
	TOTAL	**111,302**	**116,474**	**5,172**	**232,740**
Southern High off of Norumbega Supply Lines					
	Newton	47,779	49,962		
	Needham	20,260	21,033		
	Weston	4,149	3,946		
	Wellesley	16,735	17,629		
	TOTAL	**88,923**	**92,570**	**3,647**	**164,115**
Southern High off of Dorchester Tunnel					
	Brookline	17,164	17,584		
	Quincy	48,046	51,860		
	TOTAL	**65,210**	**69,444**	**4,234**	**190,530**
Southern Extra High					
	Canton	23,146	23,316		
	Dedham*	14,413	14,719		
	Norwood	23,871	25,126		
	Milton	4,998	4,990		
	Stoughton*	12,691	13,444		
	Westwood*	9,796	12,691		
	TOTAL	**88,915**	**94,286**	**5,371**	**241,695**
MetroWest					
	Framingham	43,809	46,829		
	Marlborough	32,715	34,178		
	Northborough	6,174	7,639		
	Southborough	6,527	7,688		
	TOTAL	**89,225**	**96,334**	**7,109**	**319,905**
CVA					
	Chicopee	18,931	20,843		
	South Hadley	3,540	3,762		
	Wilbraham	4,493	4,776		
	TOTAL	**26,964**	**29,381**	**2,417**	**108,765**
	TOTAL			**110,984**	**4,994,280**

* Dedham, Westwood, Reading, Stoughton, and Wilmington were not members of the MWRA water system in 2000.

5 Water Quality - Regulatory Context & Requirements

5.1 Chapter Summary

MWRA decisions about water quality and treatment are made in the context of both existing and anticipated regulations. They are also guided by the expectations of our customers about the taste, odor, appearance and safety of the water. As well as an understanding of all known potential risks of both the water itself and the treatment processes. In addition to meeting the requirements of all the applicable EPA and DEP rules, MWRA strives to meet our customer's expectations about the quality of the water we deliver. With the advent of heavily marketed bottled waters and home filtration devices, customer expectations and misinformation about tap water have become more important drivers. MWRA staff stays abreast of current health research regarding drinking water, regularly reviewing current studies and participating in professional association's expert panels, both to influence the direction of future regulations and to anticipate and prepare for water quality concerns.

Regulations, both existing and anticipated, as well as changing customer expectations, affect our partially supplied communities, on the periphery of the MWRA service area, driving short and long term local treatment investment decisions. These communities face the long term choice of either investing in local supplies or relying more heavily on the MWRA. For example, the town of Reading's decision to join the MWRA system was in part driven by a cost/benefit analysis of complying with current and future treatment regulations.

This chapter provides the regulatory context and requirements which drive decision making about water quality from the sources through treatment, transmission, distribution, and to the customers' taps.

The next chapter describes the existing treatment facilities put in place to meet those regulatory requirements, customer expectations, and outlines what will be required to maintain those facilities over time. It also discusses what new facilities and modifications will be needed to meet new and expected regulations.

MWRA staff will continue to carefully track new state and federal drinking water regulations and work with customer communities to influence the rules as they develop. MWRA will continue to provide technical assistance to communities in compliance planning.

The Master Plan recommends that:

- Recognizing the importance of local pipeline condition in preserving water quality all the way to consumers' taps, MWRA should continue to provide incentive loans totaling $210 million through the revised Local Water System Assistance Program (LWSAP) through its 2020 end date, and consider extending the program beyond that date given the magnitude of community needs, allocating loan repayments to extend the program similar to a revolving loan fund (see Chapter 8).

- Recognizing that a continued appropriately targeted program of watershed land acquisition is necessary to avoid longer term degradation of reservoir source water quality and to preserve the flexibility of MWRA remaining an unfiltered system, that $1 to $2 million be allocated annually after FY2014 for the purchase of the most critical lands which are in danger of detrimental development. These expenditures should be primarily focused on conservation restrictions, and they may not be spread uniformly year to year as the DCR takes advantage of opportunities as they arise to prevent degradation of water quality over the medium term (10-20 years).

5.2 Existing and New Regulatory Context & Requirements

MWRA is subject to a number of issued rules by the Environmental Protection Agency (EPA) under the federal Safe Drinking Water Act (SDWA)[1]. These rules, some in place for over 20 years, others issued in 2006 and not yet effective, include the protection of source water, treatment processes, allowable limits on contaminants entering the distribution system, and other requirements on water all the way though the MWRA and community distribution systems to the customer's tap. The SDWA also requires that EPA review each rule every six years, resulting in a continuing series of changed requirements. Table 5-1 summarizes the applicable current and expected future rules.

Table 5-1

Promulgated Rules – Already Effective

Trihalomenthane (THM) Rule (1979)	This rule established the first limits (maximum contaminant level or MCL) for the byproducts of chlorine disinfection. The limit for the group of THM disinfection byproducts (DBPs) was set at 100 ug/l as an annual average. Two new sets of rules have since modified it.
Surface Water Treatment Rule (1989)	This rule affects all systems using surface waters (or ground waters under the influence of surface water). It required filtration unless certain criteria on source water quality, watershed protection and disinfection effectiveness could be met. Several rounds of additional rules have added requirements to the SWTR.
Total Coliform Rule (1989)	This rule requires regular and frequent monitoring of water quality within the MWRA and community distribution systems for indicator bacteria and chlorine residual. If more than 5% of the samples in a given month are positive for total coliform bacteria, a violation occurs and the public must be notified.
Lead and Copper Rule (1991)	This rule sets "action levels" for lead and copper levels in worst case samples at selected customer's taps. It requires corrosion control, and mandates education and lead service line replacement if more than 10% of tested homes are above the "action levels."
Information Collection Rule (1996)	These rules are part of EPA's process for collecting the necessary

1 EPA issues rules under the SDWA. Generally, state environmental or health agencies in each state accept primacy under the SDWA, and issue their own rules to implement the EPA rules. Massachusetts Department of Environmental Protection (DEP) has primacy for almost all drinking water rules, and thus MWRA is usually regulated directly by the DEP, although EPA is an active participant in most decisions. Certain aspects of current rules require formal EPA concurrence, and generally it takes about 2 years for DEP to accept primacy for new rules.

Unregulated Contaminants Monitoring Rules (1995, 2005 and 2012)	information on the nation-wide occurrence of contaminants in order to determine if they ought to be regulated and what the benefits and costs of that regulation will be. The ICR collected information on *Cryptosporidium* and DBPs. The UCMR establishes a new list of microbial and chemical contaminants to be tested for every several years.
Interim Enhanced Surface Water Treatment Rule (1998)	This rule added more stringent requirements on filtration processes for those large systems which filter, and a maximum contaminant level goal and watershed protection requirements for *Cryptosporidium*.
Stage 1 Disinfection/Disinfection Byproducts Rule (1998)	This rule tightened the THM limits from 100 to 80 ug/l and added annual average limits on haloacetic acids (HAAs) at 60 ug/l and bromate at 10 ug/l. It became effective in January 2002.
Long Term 1 Enhanced Surface Water Treatment Rule (2000)	Established standards similar to those of the IESWTR for smaller systems.
Inorganic Compounds Volatile Organic Compounds Synthetic Organic Compounds	This series of rules set MCLs for specific contaminants. Periodically updated with additional contaminants.
Consumer Confidence Rule (1998)	While not strictly a water quality rule, the CCR rule requires that systems publish an annual water quality report describing the water source, how it is treated, and what contaminants are detected.
Long Term 2 Enhanced Surface Water Treatment Rule (2006)	This rule requires that systems using surface water test for *Cryptosporidium* and add additional treatment based on the levels. Unfiltered systems must achieve at least 99% *Cryptosporidium* inactivation, and must use two separate primary disinfection systems. Compliance required by 2014.
Stage 2 Disinfectants/ Disinfection Byproducts Rule (2006)	This rule further tightened standards for DBPs by requiring sampling in locations expected to be high, and by changing the averaging method. Compliance required by 2014.
Groundwater Rule (2006)	This rule requires a tiered monitoring, protection and treatment protocol for groundwater to identify and remediate the systems with the highest risk to public health. May require disinfection of many currently untreated groundwater sources, and upgrading of treatment in others.
Short-Term Regulatory Revisions and Clarifications to the Lead and Copper Rule (2007)	These changes and clarifications to the LCR included a revamped more flexible, public education requirement, better clarity on sampling and reporting schedules, and additional requirements for the review of treatment changes to attempt to identify situations where lead levels may be increased by other actions.

Proposed and Anticipated Rules

Revisions to the Total Coliform Rule (Final rule expected in late 2012 or early 2013)	It will revise the Total Coliform Rule, eliminating the MCL for total coliform, and focusing on response actions if a 5% “action level” threshold is exceeded. It is expected to require faster turnaround sampling for both total coliform and *E. coli*. Draft Rule issued July 2010.
Long Term Revisions to the Lead and Copper Rule (Draft expected late 2012 or early 2013)	This revised rule may make substantial changes to the required “worst case” sampling requirements as well as to how lead services are treated. It may also require additional sampling and education focused on higher copper levels.
Distribution System Rule	Because EPA chose to undertake a more narrowly focused revision to the TCR, it may later issue a broader distribution system rule, focusing intensively on management and control of the distribution system, including additional or better focused monitoring. It may include provisions related to unlined cast iron pipe, older poor condition pipe, and storage tank management.
Additional Chemical Rules	EPA has indicated that it is likely to move quickly toward regulating perchlorate and hexavalent chromium.

5.3 Treatment and Source Water Related Rules

The series of rules related to the Surface Water Treatment Rule, most recently culminating in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR or LT2), mandates treatment of surface water (and groundwater under the influence of surface water). Generally filtration is required, but under a narrow set of criteria very well-protected sources like MWRA's Quabbin and Wachusett Reservoirs may receive a "waiver" of the filtration requirement. Until the LT2, the SWTR was essentially a "one-size-fits-all" rule, with every system being required to remove or inactivate 99.9 percent of *Giardia*[2] regardless of source water quality. Finally under the LT2, source water quality is considered in determining the level of treatment required, with poorer quality sources (those with higher levels of *Cryptosporidium)* requiring more treatment or other protective actions.

The filtration avoidance requirements include 11 criteria, all of which must be continuously met to maintain the waiver. These criteria have not changed substantively with the recent rules.

- Low levels of source water quality fecal bacteria
- Low levels of source water quality turbidity
- Adequate watershed protection
- Adequate inactivation of *Giardia* and viruses
- Redundant disinfection equipment to ensure reliability
- Adequate and consistent disinfectant residual levels at the entry point
- Adequate disinfection residual levels within the distribution system
- Compliance with the disinfection byproducts rules
- Low levels of total coliform bacteria within the distribution system
- No evidence of waterborne disease outbreaks
- Adequate performance on annual on-site inspections

MWRA Compliance History with Surface Water Treatment Rule

When the SWTR came into effect, the Wachusett Reservoir did not initially meet the avoidance criteria, as source water fecal bacteria levels were substantially over the allowable limit. As a result, while a watershed protection plan was developed, an initial decision was made in 1991 to build a filtration plant. Subsequent implementation of the watershed plan by the MDC (now DCR[3]) Watershed Division demonstrated that the high bacteria levels were due primary to flocks of gulls roosting on the Wachusett reservoir. Employing various actions to reduce the attractiveness of the region to gulls by better management of local landfills, and harassing the gulls at dusk reduced the number of roosting gulls and bacteria levels dropped dramatically, bringing the reservoir into compliance with this source water criterion by 1993. MWRA then entered into a dual track scheduling Administrative Consent Order with DEP: the ACO required

2 *Giardia* and *Cryptosporidium* are two protozoan pathogens which can cause gastro-intestinal illness. Both are excreted with the feces of certain warm-blooded animals, and exist in the environment in a protective cyst which protects them from certain kinds and levels of disinfection. Because they are hard to disinfect, they are used as the target organism in various rules.

3 Hereinafter, all references to the Watershed Protection Agency, whether to the MDC or later to the DCR, will simply be made to DCR.

the siting and design of a filtration plant, but allowed MWRA and DCR until 1998 to demonstrate compliance with all criteria and request a waiver of filtration just prior to construction. The watershed protection plan and related activities are discussed later. This section provides a very brief overview of MWRA's compliance history as it is germane to the decision process on treatment going forward. A slightly longer version was presented in an attachment to the 2006 Master Plan providing more background on the treatment technology decision process.

As the decision point in 1998 approached, MWRA staff provided a wide ranging series of briefing documents to the Board of Directors on treatment, and in October 1998 the Board decided to request from DEP a waiver of the filtration requirement. As part of this, MWRA would continue as an unfiltered water system and implement an integrated water supply improvement program from the source reservoirs to the consumers' taps. The $1.7 billion 10-year program would include improvements to watershed protection, completion of the Metro-West tunnel, building an ozone disinfection facility capable of inactivating *Cryptosporidium*, replacing all MWRA open distribution reservoirs with covered storage, implementing a $250 million zero-interest loan program for communities to replace old unlined cast iron water mains[4], and a commitment to monitoring water quality and health outcomes and re-evaluating the decision once the plant was on-line.

DEP approved MWRA's decision, but the Environmental Protection Agency disagreed with MWRA's approach and sued in federal court. After an extended legal process, MWRA's decision was upheld, and the ozone plant, dedicated as the Carroll Water Treatment Plant, was constructed and placed into operation in July 2005. The plant has generally performed as expected. Inactivation was greatly increased, reaching the site-specific inactivation targets of 99 percent inactivation of *Cryptosporidium*, as well as greatly increasing the inactivation of viruses and *Giardia* beyond those required by regulation. Disinfection byproduct levels were reduced even more dramatically than anticipated. While a higher chloramine dose than originally anticipated was required, once adjusted, disinfection residuals throughout the distribution system were generally as good as or better than before.

The Quabbin Reservoir had a much less significant issue with roosting gulls, and met the source water quality criteria. MWRA and DCR implemented the watershed protection plan, built interim disinfection facilities by reusing an existing chlorine injection system, and then proceeded to design and build a modern chlorine disinfection facility in Ware (2001) and replace the open distribution reservoir at Nash Hill with two covered storage tanks (1999).

New Treatment Rules

All the while MWRA was working towards the construction and operation of new facilities to comply with the SWTR, EPA was developing new rules as described in Table 5-1. While several new rules relating to surface water treatment and disinfection byproducts were promulgated during this period, none had a substantive impact on the decisions made and the processes being built. The CWTP came on line, and complied with all current regulations in July 2005.

4 The Local Pipeline Assistance Program made available approximately $256 million through FY13, and was extended and modified as the Local Water System Assistance Program.

In January 2006, EPA issued their long anticipated new microbial and disinfection products rules[5]. These two rules required upgrades to both the CVA and metroBoston treatment systems, and mandated changes in monitoring programs.

The pair of rules, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2, for short) and the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 D/DBP or Stage 2), focused on the control of *Cryptosporidium* and on further reducing the amounts of chlorine disinfection byproducts to which consumers are exposed. These two rules were the latest in a series of rules focusing on these issues. The LT2 Rule brought to closure EPA's efforts since the Milwaukee *Cryptosporidium* outbreak in March 1993 to tighten drinking water treatment to protect against that pathogen. It was also the first microbial treatment rule to consider source water quality in mandating treatment levels, moving away from EPA's former "one-size-fits-all" approach. The Stage 2 Rule marked a shift in EPA's focus on disinfection byproducts from only looking at the long-term cancer health outcomes of disinfection byproducts to the possibility that they might also have shorter term developmental or reproductive effects (low birth weight, birth defects or miscarriages).

The two rules were developed in tandem because of the recognition that there is a strong potential for what is called a risk-risk trade-off: improvements to inactivate more pathogens may cause utilities to take actions that increase disinfection byproducts or improvements to reduce disinfection byproducts may actually reduce the effectiveness of treatment against pathogens[6].

The focus of the pathogen rules since 1993 has been on understanding and controlling the potential risk due to *Cryptosporidium*. In March 1993, over 400,000 thousand people became sick and as many as 100 died in Milwaukee due to an outbreak of *Cryptosporidiosis* caused by inadequate treatment of polluted source water. Research since then has shown that *Cryptosporidium* can be very infectious, with as few as one oocyst needed to infect an individual, that many source waters contain the organism, and that some infectious oocysts can and do breach even well-run conventional filtration plants. It is clear that nationwide some systems are at risk. MWRA conducts very sensitive tests for *Cryptosporidium* and occasionally finds evidence of its presence, at very low levels, but generally only empty oocysts regarded as unlikely to be infectious.[7] No firm conclusion about health risk can be drawn given the

5 The rules were developed using a regulatory negotiation process under the Federal Advisory Committee Act (FACA), which allows the creation of stakeholder committees (called FACAs) to agree upon and recommend approaches to complex regulatory issues. The interests of unfiltered water systems were provided a specific representative on the panel, and MWRA was an active caucus member and commented on pre-proposal and official drafts throughout the process. The FACA process began in essentially in November 1997 and culminated in September 2000 with an Agreement in Principle (AIP) which represented the compromise position of all the stakeholders. As reported to the Board at that time, notable in the agreement was the "deal" that there would remain an unfiltered option, but that unfiltered systems would use two primary disinfectants as a "multiple barrier" and provide at least 99% *Cryptosporidium* inactivation. Over the next 5 years, EPA developed the draft and final rules based on the compromises reached in the AIP. Staff provided a series of updates to the Board on the evolving regulations.

6 It has also become increasing clear that this issue of "simultaneous compliance" affects all attempts to improve treatment and water quality. Corrosion control efforts can affect disinfection effectiveness, and changes in disinfection or filtration chemicals can affect corrosion control and cause lead levels to increase.

7 The current EPA approved testing protocol for *Cryptosporidium* calls for filtration and examination of 10 liters of water. The test has relatively low recovery efficiency (approximately 40%) and cannot actually distinguish whether

inadequacies of current testing methods, but MWRA levels would be considered very low even based on levels leaving conventional filtration plants, and MWRA's current ozone treatment provides some inactivation of any oocysts that are potentially infectious.

Concurrent with the attention on *Cryptosporidium*, EPA was under increasing pressure to recognize that the format of its earlier rules presented essentially a "one-size-fits-all" approach to a more complex nationwide situation. EPA's own research agenda[8] clearly pointed out the fallacy of that approach, showing that some locations had too little protection, while others may have been forced into over-investing on unneeded protection. Thus the big push in the development of the LT2 rule was to develop a risk based regulation, with treatment tailored to the degree of risk. The LT2 called for tiered treatment by both filtered and unfiltered water systems based on testing of *Cryptosporidium* levels in source water; retained an option for unfiltered systems; and mandated changes in existing uncovered distribution storage reservoirs.

The retention of the unfiltered option was a significant victory, as the additional requirements for remaining unfiltered – 99% *Cryptosporidium* inactivation and use of a second primary disinfectant – were reasonably achievable and significantly less costly than filtration.

For the MWRA system, the most important impacts of these new regulations are:

- required inactivation of *Cryptosporidium;*
- required second means of primary disinfection: and
- higher than anticipated "CT" requirements that translate into higher ozone doses.

Combined, these standards required the addition of a second disinfection process at both the John J. Carroll and Ware Water Treatment Plants by 2014. As discussed in more detail in Chapter 6, MWRA will meet the requirements by adding ultraviolet light (UV) disinfection at both plants.

New research on disinfection byproducts continues to raise the possibility that in addition to risks for certain cancers, high levels of DBPs may affect the developing fetus, possibly resulting in lower birth weight, developmental problems or birth defects, and miscarriages. While the science is still uncertain on this issue, and research papers both supporting it and suggesting that there may not be an effect continue to be published regularly, the level of concern is such that the consensus of those working on the new regulations thought that it was prudent to call for reductions[9]. The new rule shifted the focus from a long term average exposure across the entire region, to shorter term exposures in specific locations.

Essentially the new Stage 2 D/DBP rule requires that water systems look for chlorinated DBPs where they are most likely to be high, and then adjusts the compliance calculation to focus on an annual average at each of these locations. If any single location is above the MCL, then the

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the oocysts are live and potentially infectious. MWRA tests raw water weekly at the CWTP and every other week at Quabbin, and filters and examines 50 liters. MWRA also conducted a multi-year research study using weekly 1000 liter samples collected at Shaft 9A in Malden.

8 Draft Report on Research to Support New Rules, EPA, November 12, 1997

9 There have been two research papers published on MWRA water (prior to the start-up of the Carroll Water Treatment Plant) suggesting a potential effect on birth weight, but each has had methodological issues weakening the power of the conclusions. In any case, the level of disinfection byproducts has been dramatically reduced by the switch from free chlorine to ozone for primary disinfection.

system is in violation of the rule. Previously, all locations, both high and low, are averaged together. This new locational running annual average (LRAA) has the effect of reducing the chance of higher exposures. There are also provisions dealing with how to respond to individual high results even when a system remains in compliance and on preventing treatment changes intended to reduce DBPs from degrading pathogen inactivation. The rule made no change in the standard of 10 ug/l for bromate, a byproduct of ozonation of water with elevated levels of bromide.

For the MWRA system, there should be little impact beyond the requirement the DBP sampling program be expanded from 15 to 32 sites each quarter. Bromate levels are not expected to be a problem, and the dramatic reductions in THMs and HAAs brought about by the switch from free chlorine to ozone for primary disinfection will mean that no fully supplied community should have any risk of exceeding the new standard[10].

5.4 Distribution System Rules

The principle current rule related to water quality within the distribution system is the Total Coliform Rule, promulgated in 1989. The rule requires an extensive monitoring program at locations within the distribution system which are representative of system wide water quality. Each community and MWRA have their individual monitoring program. Across the MWRA/community system, over 2,400 samples are collected each month at over 460 locations. Larger communities collect samples weekly; smaller ones less frequently; and MWRA collects samples at key locations daily. Each sample includes a total coliform result, a chloramine residual measurement, temperature and heterotrophic plate count (HPC) bacteria results if the chloramine residual is very low.

The total coliform test is an *indicator* of overall water quality – not a direct test for pathogens. Total coliform bacteria can come from the intestines of warm-blooded animals, or it can be found in soil, plants, or other places. Most of the time, these bacteria are not harmful. However, their presence could signal that harmful bacteria from fecal waste may be present as well. The TCR requires that no more than 5 percent of the samples in a given month may be positive for total coliform. If a water sample tests positive for total coliform, more specific tests for E. coli are conducted. *E. coli* is a specific coliform species that is almost always present in fecal material and whose presence indicates likely bacterial contamination of fecal origin. If *E. coli* are detected in a drinking water sample, this is considered evidence of a critical public health concern. Additional testing is conducted immediately and joint corrective action by DEP, MWRA, and the community is undertaken.

If more than 5% of all samples are total coliform positive in a month (or more than one sample when less than 40 samples are collected each month), the community has <u>violated</u> the TCR, and public notification is required usually via advertisement in the local paper. Public notification is also required if follow-up tests confirm the presence of *E. coli* and a boil order may be required.

10 In addition, the low levels allowed MWRA and the communities fully supplied by the CWTP to avoid an initial extensive sampling program, for a one-time savings of about $500,000.

The total coliform rule monitoring program is jointly conducted by MWRA and the communities. Communities conduct the actual field sampling, and MWRA's laboratories do the analysis and reporting. In addition, a portion of MWRA's TCR monitoring program includes the results from the community sampling location nearest the MWRA connection.

The total coliform sampling results are also used in the aggregate as one of the criteria for maintenance of the filtration waiver. No more than 5 percent of all samples from fully supplied communities system-wide in any month can be positive

With improvements to treatment and the removal of the open distribution reservoirs, the system wide total coliform positives have been reduced substantially since the mid 1990's.

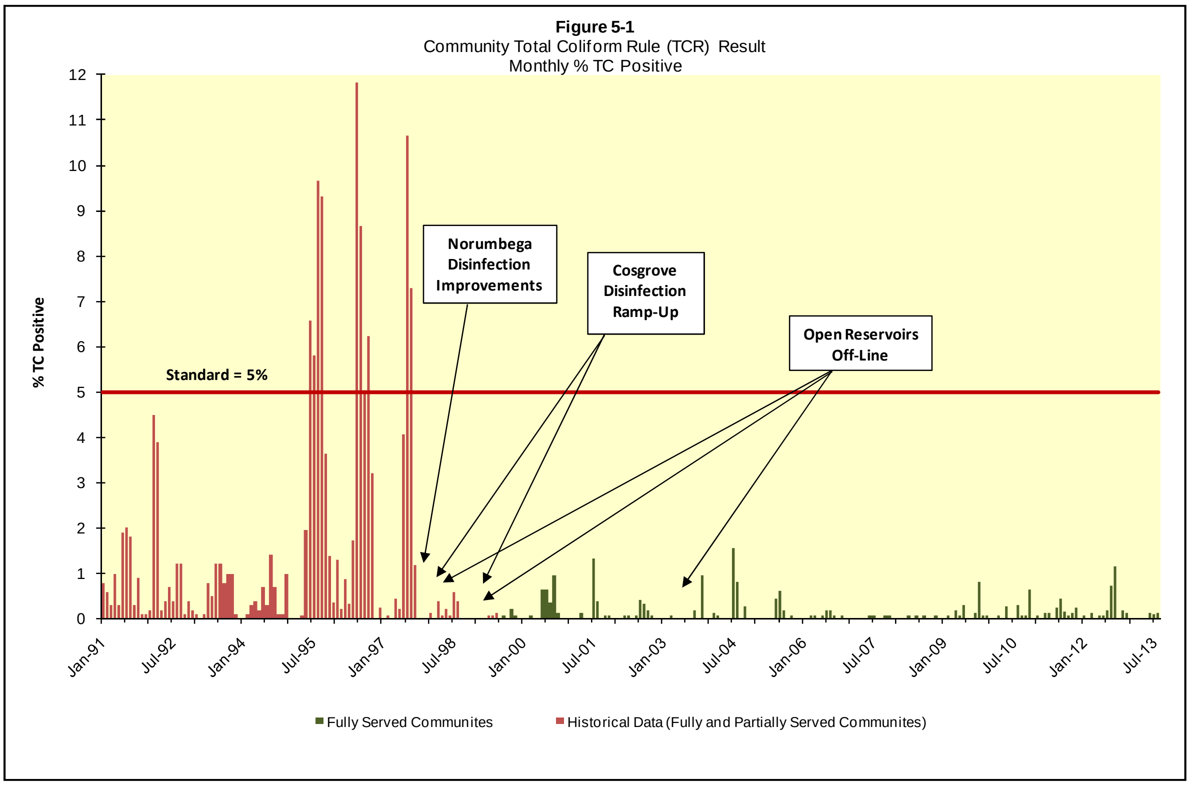

Figure 5-1
Community Total Coliform Rule (TCR) Result
Monthly % TC Positive

While the aggregate results are much lower, there are still occasional total coliform positives both within the MWRA system and in some community systems. Often there is a single positive sample, and none of the repeat samples are positive. These are difficult to categorize and assess. Other community positives are related to local distribution issues, especially storage tanks and low chlorine residuals. When these occur, communities can take local action to improve the residuals by flushing or tank draining, and the situation corrects itself. Less frequently, communities will have actual contamination within a tank, and the tank must be drained and cleaned.

One area of potential concern has to do with "nitrification" within community systems. MWRA tracks chloramine residuals in pipes and tanks, not just because it is needed as a distribution system disinfectant, but because when the residual is reduced, it frees up ammonia. Chloramine is made up of chlorine and ammonia – combined they produce chloramine which is a very mild and long lasting disinfectant, ideally suited to a system like the MWRA/community system with over 5000 miles of local pipes. However, when chloramine breaks down and ammonia is released, a type of bacteria called ammonia oxidizing bacteria (AOB) can consume the ammonia, creating nitrite and then nitrate which further reduces the chloramine residual in a positive feedback situation. If not controlled, this type of situation can get out of control, potentially resulting in no disinfectant residual at all. Water systems must maintain an adequate chloramine residual throughout their pipe network by managing water age, allowing tanks to cycle in two to five days and improving the condition of pipelines. MWRA staff provide technical assistance to communities as needed, and the Local Water System Assistance Program now grants funds for storage tank improvements, distribution system master planning, and the elimination of old unlined cast iron pipelines.11

Positive total coliform samples within the MWRA system have also been substantially reduced especially since the ozone plant went on-line, although the system still does experience some positive samples. MWRA has never violated the TCR within its own system. Occasional positive samples can occur at almost any sampled location; however, in the summers of 2005 and 2006 there are more frequent positive samples just downstream of treatment within the CWTP[12]. MWRA implemented a series of minor treatment and maintenance changes by relocating the chlorine injection location at the CWTP and conducting annual tank cleaning, and the positive tests have been substantially reduced.

Along with the bacteria results from the community and MWRA distribution systems, MWRA tracks the chloramine residuals. There is an upper regulatory limit on the annual average of these samples of 4.0 mg/l, but as levels at the entrance to the distribution system are typically 2.5 to 3, it is unlikely that the MWRA or community systems would exceed the limit. More important is the reduction of chlorine residuals across the distribution system, and what the lowest levels are. As with total coliform results, treatment changes over the past decade have resulted in substantial improvements.

MWRA considers a disinfectant residual of 0.2 mg/L a minimum target level at all points in the distribution system. Many of the community systems currently have at least one location which does not meet the MWRA goal. Generally this is due to the condition of community pipes, and to prolonged detention with pipes and tanks in the community system. In addition to the *goal* of no locations below 0.2 mg/l, MWRA maintains a triggering level based on the number of samples below 0.1 mg/l. If the percentage of samples below 0.1 mg/l exceeds 5 percent, MWRA adjusts treatment and considers other actions. Generally these levels are between 2 and 3 percent each month.

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11 At least one community has experienced substantial nitrification in recent summers, possibly due to distribution system issues, excessive water age in local tanks, and the use of free chlorine at its local source. MWRA staff have provided substantial technical and logistical support, but the problem is not yet completely resolved.

12 These positive samples occur at the "Finish Water A and B" locations (typically noted as Fin A or Fin B). They were more common during warmer water conditions, and appear to have been related to having section within the treatment plant between the point of ozonation and chloramination with no disinfectant residual during those conditions.

Table 5-2 Improvements to Distribution System Chlorine

	Chlorine Residual Below 0.2 mg/l	Chlorine Residual Above 1.0 mg/l
1995	57%	2%
1996	47%	1%
1997	33%	5%
1998	8%	51%
1999	3%	74%
2000	5%	76%
2001	4%	75%
2002	5%	70%
2003	4%	63%
2004	5%	69%
2005	5%	71%
2006	5%	75%
2007	2%	84%
2008	2%	87%
2009	4%	83%
2010	3%	84%
2011	3%	85%
2012	6%	80%

MWRA has had a long standing program of monitoring water quality in storage tanks on a weekly basis. A chloramine trigger of 1.0 mg/l is set: immediate action is taken to improve the residuals of a weekly sample is less than that. With the recent addition of the on-line contaminant monitoring system, tanks are monitored continuously, for more parameters, and action can be taken more quickly if chloramine residuals appear to be dropping or nitrification appears to be increasing. Typically response actions are to cycle the tank more rapidly and more deeply, "freshening up" the water and improving residuals. If that is insufficient, the tank may be drained and refilled or drained, disinfected and then refilled.

5.5 New Distribution System Requirements

The Microbial and Disinfection Byproducts (M/DBP) Federal Advisory Committee (FACA) which negotiated the LT2 and Stage 2 rules, also agreed in principle that valid health concerns from distribution systems existed, and that EPA should review available data and research on distribution system risks and work further with stakeholders. These efforts were expected to result in the review and possible revision of the TCR, as well as the potential for requirements to address finished water quality in the distribution system.

As EPA began to consider what might need to be changed in the Total Coliform Rule in 2002, and solicit input from utilities and others, it became clear that simply updating the TCR might not be sufficient. Therefore EPA began an effort to potentially replace the TCR with an entirely new Distribution System Rule. EPA, in association with distribution system experts, compiled existing information regarding potential health risks that may be associated with distribution systems in "white papers" on nine distribution system issues to inform EPA and stakeholders of areas of potential TCR revisions and distribution system requirements:

- Intrusion
- Cross-Connection Control
- Aging Infrastructure and Corrosion
- Permeation and Leaching
- Nitrification
- Biofilms/Growth
- Covered Storage
- Decay in Water Quality over Time
- New and Repaired Mains

MWRA staff tracked and participated extensively in the research and rule development process. Ultimately, EPA chose to revise the TCR, and to continue research and information collection on distribution system issues in anticipation of further regulatory action at a later time.

The proposed revisions to the Total Coliform Rule which was promulgated by EPA in February 2013 include:

- Eliminating the maximum contaminant level (MCL) for total coliform, and
- Replacing it with an action level of 5%;
- Replacing the required (and confusing) public notice with a series of required investigations designed to understand distribution system problems resulting in total coliform positives;
- Defining a rule violation as failing to conduct the investigations following an exceedance of the 5% action level or failing to follow up on recommendations; and
- Retaining the *E. coli* MCL and required actions for exceeding it.

Massachusetts DEP is anticipated to fast track adoption of the revised TCR with an expected issuance of final regulations in early 2014.

EPA is continuing to evaluate testing procedures and may also require changes to the laboratory analysis procedures to more rapidly assess water quality. Some current approved methods can take up to 5 days to determine if there is an *E. coli* positive.

MWRA has carefully tracked theses rule changes, and has already modified its laboratory procedures, and has worked with communities to conduct investigations of the type likely to be required by the revised rule. The elimination of the unnecessary public notification will be a welcome change.

It is clear that as treatment has improved nationwide, there are still potentially important risks to water quality and public health after the water leaves the treatment plant. MWRA's approach to investment over the past decade mirrors that understanding, focusing on water quality all the way to the tap with substantial investments in MWRA distribution system storage and MWRA and community pipeline rehabilitation. Looking at the range of issues in the EPA white papers, it is clear EPA will likely continue to take a more careful look at storage tank maintenance and operation, internal condition of pipes, the possibility of contamination getting in through small holes in pipes and aging infrastructure and corrosion. The degradation of water quality which occurs as the water "ages" in pipes and tanks, and the potential of pathogen growth (or at least increased biological activity) within the pipes may also be important.

MWRA already has adopted many of the best practices for operations and maintenance being discussed, so the impact on the MWRA system operations may be limited. Some community systems may be less prepared to comply with any new requirements.

It is also clear that many of the potential distribution system health risks (or at least opportunities for degradation in water quality) are related to the age and condition of the buried infrastructure. There is a substantial potential for increased attention and investments by communities in their own distribution systems. The recommended remedial action for many of the identified problems is essentially rehabilitation of old unlined cast iron pipelines, and replacement of pipe which is in poor condition. MWRA created a pilot grant/loan program that distributed $30 million to member water communities in FY98-99 substantially for pipeline improvement projects. Based on the initial success of the pilot financial assistance program, MWRA created the Local Pipeline Assistance (interest-free loan) Program as part of the 1998 Board Decision on Treatment Technology recognizing that regardless of the level of treatment provided by MWRA, the water must pass through the local community pipe network before reaching customers. The Local Pipeline Assistance Program distributed $222 million in zero interest, 10-year loans for the rehabilitation or replacement of member community unlined cast iron pipe from FY00-13. Prior to the pilot program, about 40 percent of water pipe in community systems was unlined. Since then (through FY13), over 450 miles of local pipe rehabilitation or replacement has been completed (about 7 percent of the system), the majority having been financed through MWRA loans.

As recommended in the 2006 Master Plan, in FY11 MWRA launched the Phase 2 Local Water System Assistance Program (LWSAP) to continue providing zero interest, 10-year loans for member water community projects. The Phase 2 program is budgeted at $210 million for FY11-20. The revised program expanded the eligible activities to include system master planning efforts, storage tank rehabilitation and efforts to improve water accountability such as improved metering. Even with this additional funding, there is still a long way to go before all the old unlined tuberculated pipe is removed from local distribution systems. MWRA estimates, at current rehabilitation/replacement rates, it will take another 75 years and a regional investment of $1.0 to $1.5 billion before the last of the community unlined water pipe is removed.

<u>Recommendation-Distribution System</u>

- *Recognizing the importance of local pipeline condition in preserving water quality all the way to consumers' taps, MWRA should continue to provide incentive loans totaling $210 million through the revised Local Water System Assistance Program (LWSAP) through its 2020 end date, and consider extending the program beyond that date given the magnitude of community needs, allocating loan repayments to extend the program similar to a revolving loan fund (see Chapter 8).*
- *MWRA will also need to find additional ways to encourage a continued long term program of local distribution system rehabilitation.*

While MWRA cannot directly affect the rate of community efforts to deal with poor quality pipelines, and as MWRA pipeline rehabilitation will also take decades to complete, source water quality, treatment and potential distribution system impacts of treatment are within MWRA's more immediate control.

5.6 Interaction between Treatment and the Distribution System

Once water leaves the treatment plant, it continues to change as it travels through the distribution system. The type of treatment, the characteristics of the source and finished water, the condition of local infrastructure (pipes and tanks) and the total travel time all affect how stable the water quality is as it travels to the ultimate customer. Ozone breaks down complex naturally occurring organic carbon compounds into smaller compounds. There is concern that increased levels of these smaller compounds, referred to as biologically degradable organic carbon (BDOC) or assailable organic carbon (AOC) could lead to the proliferation of biological activity within the distribution system. Frequently, biologically active carbon filters are added after ozone to capture the BDOC by allowing bacteria to grow and feed upon the organic material in the water. During the treatment technology decision process, extensive research on this topic was undertaken to determine if filtration would be required after ozonation in the MWRA system, using both laboratory bench scale and pilot testing using actual old tuberculated cast iron water mains. Based on the results of the research, MWRA and its research team drew the conclusion that proper corrosion control and the maintenance of an adequate chloramine residual throughout the system were more important than the level of BDOC in preventing issues within the distribution system. Based in part on those research conclusions, MWRA decided that treatment with ozone alone was feasible. The performance of the distribution system and levels of chloramine residual would be carefully watched after the treatment change.

There have not been indications of widespread distribution system problems since the ozone plant went on-line in 2005. The initial dose of chloramine was raised somewhat, and with the higher initial dose, residual levels throughout the system were able to be maintained at least as high as prior to startup. As discussed above, there have been some indications of increased nitrification in areas with very high water age, particularly in certain community or MWRA tanks, but there does not appear to be any system-wide change at this point. Given the potential for degradation of disinfectant residuals with nitrification, MWRA staff will continue to closely monitor this, and work with communities to control it. Overall total coliform levels are similar or lower than previous years, although there were initially some localized issues immediately downstream of the CWTP as discussed above which have been resolved.

If it is determined that the nitrification presents a problem which cannot be resolved by changes in how the plant and system are operated, it is possible that additional remedial actions will be required including community flushing programs, higher chloramine levels, and more aggressive targeted pipeline rehabilitation efforts.

5.7 Organic and Inorganic Contaminant Rules

MWRA is required to test for and meet maximum contaminant level (MCL) standards for over 100 specific chemicals. Generally only a few are found and at levels well below the MCL. Results are required to be included in MWRA's annual water quality report each year and generate a few questions from consumers. MWRA has never failed an MCL for any of these regulated contaminants.

The SDWA requires that EPA engage in a periodic process to determine whether additional contaminants should be regulated, and Massachusetts has a parallel independent process as well. The process generally includes research into chemicals which may potentially have negative health effects, and which may be present in drinking water. Once these candidates are identified, EPA or the state will require that systems conduct "occurrence" sampling to estimate the prevalence and levels of the chemical. If the toxicological and epidemiological research indicates there is a potential health effect, AND the chemical is present AND EPA determines that there is a meaningful way to effect a health risk reduction, then they will issue a standard. This lengthy process can result in an interim situation where the public receive information about the potential presence of a potentially harmful chemical long before a consensus (or perhaps even evidence) of what constitutes a safe level is available.

For well protected sources such as MWRA's, this process generally (but not always) results in our being able to simply say we didn't find the chemical. Less well protected sources will find trace levels more frequently.

Lower detection levels/ more chemicals detected - An area which may have profound effects on how water systems operate in the future is the continued trend toward lower detection levels for all sorts of natural and human-made environmental contaminants. While a few years ago water suppliers were mostly concerned about chemicals measured in part per million (milligrams/liter), detections have since moved to parts per billion (micrograms/liter) and more recently to parts per trillion (picograms/liter)[13]. Concurrent with the increased ability to find ever smaller amounts of chemicals in water is the science of evaluating their health effects. While the science of detection is always necessarily ahead of the science of understanding the health implications, researchers now regularly publish epidemiological or toxicological findings which cast doubt on the safety of chemicals which may be found in water. These may or may not eventually be determined to be of sufficient concern to be regulated, but their presence does raise concerns among consumers.

This is one area where MWRA's undeveloped watersheds are an important asset. While most water systems using surface water across the country rely on water which has passed over

13 In each case a thousand fold less of the chemical of concern. A practical comparison is that a part per million represents about one drop in a 55 gallon drum, a part per trillion is less than one drop in an Olympic sized swimming pool, and a part per trillion would be less than one drop in a thousand swimming pools.

developed areas and includes often substantial amounts of treated wastewater, MWRA's sources are much closer to pristine. An area receiving increasing public and scientific interest is trace amounts of pharmaceutical and personal care products (often referred to as PPCP). Wastewater generally contains some amount of these chemicals, and studies by the USGS have detected them in most surface waters. At this point, relatively little is known about the effects of very low amounts of these chemicals on human health, but there are concerns that they may disrupt important hormonal processes, especially in growing fetuses and children. (More likely is that there could be ecological impacts on fish and amphibians at levels well below human health concern.) MWRA would not expect to find PPCP in its source waters, and tests conducted in 2008 of a well-rounded selection of 31 pharmaceuticals, hormones and potential endocrine disrupting compounds detected none in source or finished water.

MWRA must regularly respond to customer concerns about chemicals or health risks reported in the media. Most frequently, we can report that we have tested for the chemical and that it is not present in the water we deliver. However, as detection limits decrease, it becomes increasingly likely that we may find some very small levels of chemicals and have to report on or otherwise disclose that information. Because it is almost always the case that the reports of possible health effects and detection in the environment or in drinking water will be years prior to a definitive assessment of safe levels, there is little that can be done to reassure consumers. Our goals for source water protection and treatment are designed to reduce the potential for harmful levels of environmental, human-caused, or treatment-related contaminants, but as knowledge evolves, we may find unexpected issues.

Increasingly, attention has been focused on trace levels of regulated contaminants in the treatment chemicals used by water suppliers. Perchlorate can be constituent of the sodium hypochlorite used for disinfection. It has been regulated in Massachusetts since 2006 with an MCL of 2 parts per billion (ppb), and EPA is working towards issuing a draft rule in 2013 or 2014. While MWRA does detect trace amounts of perchlorate in finished water due to the very sensitive testing methods used, the amounts are well below the state standard.

MWRA specifies strict limits on the allowable limits of any expected trace contaminants in our chemical procurements, does regular testing, and periodically reviews the specifications to avoid (if possible) adding detectable amounts of reportable chemicals to the water.

A series of numbers accompanies each drinking water regulation: the MDL, the PQL, the MRL, the MCLG, the MCL and sometimes an AL.

Each regulation specifies a laboratory technique(s) to be used in detecting and quantifying the contaminant. The method detection level (MDL) is the lowest level at which the laboratory can assure the chemical is present, but it cannot be reliably quantified. The practical quantification level (PQL) specifies the lowest level at which the laboratory can say that the chemical is present and tell what the amount is. The method reporting level (MRL) is the level above which a water system must report that it has detected a chemical. It is typically set near or at the PQL. Typically if a chemical is detected below the MRL it does not need to be reported to the regulatory agency.

The MCLG or maximum contaminant level goal is a non-enforceable goal. It is set by EPA and is the level of contaminant in drinking water below which there is no known or expected risk to health. MCLGs are required to allow for a margin of safety. The Maximum Contaminant Level (MCL) is the enforceable standard, and is the highest level of a contaminant allowed in water. MCLs are required to be set as close to the MCLGs as feasible using the best available technology. Both the MCL and MCLG must be reported to the public, which occasionally can cause confusion about whether a contaminant detected above the MCLG is still "safe". There is no good answer to the question.

In some cases, EPA will set an action level which is essentially a trigger for certain actions, such as corrosion control or mandatory education. EPA can also set a treatment technique if a contaminant is not easily measured, but can be controlled by a specified level of treatment such as disinfection or filtration. In addition, both EPA and DEP may sometimes set a health advisory level which may require action or notification to consumers.

5.8 Potential for Regulation of Additional Ozone, Chloramine or UV DBPs

Researchers continue to identify additional compounds created when disinfectants react with natural and man-made substances in the source water. EPA continues to review the toxicological and epidemiological data associated with any potential health risk associated with these disinfection byproducts. In the past several years, their attention has moved beyond just the byproducts of chlorine to those of other disinfectants. Some of the byproducts of chloramine are already regulated, as is one ozone byproduct. To date no potential byproducts of UV have been identified.

The Unregulated Contaminants Monitoring Rule requires that water systems provide data to EPA on certain unregulated contaminants so that EPA can determine how widespread their occurrence is. Results are available from the 2006 UCMR and testing will occur between 2113 and 2015 under the 2012 UCMR. Of the many dozens of chemicals that have been or will be looked at nationwide, only a couple are likely to be of significant concern to MWRA: nitrosamines (specifically NDMA) and hexavalent chromium.

Chloramination has the advantage of producing very little of the two primary regulated DBPs – HAAs and THMs, but at least one class of byproducts of potential health concern – nitrosamines - can be produced by chloramination[14]. None of the nitrosamines are regulated by EPA at this time, but advisory or guidance levels have been set by Massachusetts and California at 10 parts per trillion (nanograms per liter) for one of them, N-Nitrosodimethylamine (NDMA). EPA has listed NDMA on its Contaminant Candidate List; it was detected in about one quarter of systems tested; and a decision on whether it will be regulated is expected in the next year. As more water

14 NDMA can also be a direct source water contaminant from certain industrial processes, and a byproduct of certain water filtration processes using polymer coagulants.

systems adopt chloramination to comply with the new DBP rules, it is likely that additional byproducts of concern will be identified, and possibly regulated.

MWRA and our fully and partially supplied communities could all be affected by new chloramine byproduct regulations. In seven rounds of testing of MWRA water, no NDMA was found in raw water, water right after treatment, or in water at an average detention time site. Detections were limited to the site selected as typical of the longest detention time. At that location, levels generally ranged from 2 to 5 ppt, about one half the DEP guidance limit.

Hexavalent chromium is noteworthy as the contaminant made famous in the movie ***Erin Brockovich*** starring Julia Roberts. Hexavalent chromium is not regulated in drinking water by EPA or any state at this time, but EPA is considering regulating it. California has established Public Health Goal for hexavalent chromium of 0.02 ppb. This is a non-enforceable goal designed to be at a level below which there is no health risk, with a margin of safety. In August 2013, California issued a proposed maximum contaminant level (MCL) of 10 ppb. EPA does regulate total chromium at 100 ppb. MWRA's total chromium levels have typically been below 1 ppb. Chromium is a relatively abundant element, and trivalent chromium (chromium-3), the more common form, is an essential nutrient with recommended daily allowances of 20-45 ug/day. Hexavalent chromium is another form of chromium and would normally be detected (but not specifically identified) as part of the total chromium measurement. While most of the publicized cases of occurrence of high levels of hexavalent chromium in water have been from industrial contamination, the most common form of chromium - trivalent chromium - can switch back and forth to hexavalent chromium in the presence of oxidants such as chlorine or ozone.

MWRA conducted one year of quarterly samples of raw water, finished water right after treatment, and at four locations within the distribution system. The results were very low – just above the method detection limit detection level of 0.02 ppb (or 20 nanograms per liter or parts per trillion). All but one of the 96 results were below the lab's minimum reporting level of 0.05 ppb. This indicates that the chemical was present at very low levels, but the actual quantities can only be estimated. More recently, initial results from the UCMR-3 testing also show detections at very low levels ranging from non-detect to 0.06 ppb. All were well below the proposed California MCL of 10 ppb.

Ozone is a powerful oxidant and can transform many of the naturally occurring compounds in water. To date, only one ozone DBP is regulated – bromate - at an annual average MCL of 10 ppb. Generally bromate is produced when water containing bromide is ozonated. *MWRA's source water has relatively low levels of bromide, and it appears that levels of bromate will remain well below the MCL*[15].

15 Bromate is also an identified trace contaminant in the sodium hypochlorite, which MWRA uses to produce chloramines. Two monthly samples have had detectable levels of bromate since the CWTP was brought on line. It appears that the bromate was not produced by ozonation, but was most likely from the sodium hypochlorite. MWRA's purchase specifications should prevent this from happening, and there have been no additional detections since this issue was brought to the attention of the chemical vender.

5.9 Uncertainty, Margin of Safety, and Perceived Risk

An area receiving increased attention on the national stage is how to set regulations and make public resource allocations decisions in the face of scientific uncertainty about the effects of various chemical or biological contaminants. The scientific community understands that how risks are understood and described can and will affect the policy debate over a particular contaminant, but there is not a consensus about how to best deal with uncertainty in risk estimates. Some believe that any risk is unacceptable, and that if the degree of the risk (or perhaps even the existence of an actual risk to health) is unknown or uncertain that a precautionary approach should be taken. In practice for water suppliers this might mean that any potential contaminant which has been described as a risk in any single animal toxicological study or preliminary epidemiological study should be regulated and removed from the water. Others believe that a weight of evidence approach is appropriate, and that action should wait until there is some reasonable certainty that an actual effect may happen at doses likely to be experienced by consumers. In practice for water suppliers this might mean that a potential risk would exist and be publicly discussed for many years before action is required. Neither approach seems particularly satisfying. MWRA's approach to date has been to stay abreast of health and contaminant research and the regulatory process, and armed with that information, examine the potential risks in the MWRA system. *If a risk seems plausible, MWRA undertakes specific investigations on whether the contaminant occurs or is likely to occur in our water. In some cases, such as with Cryptosporidium, MWRA began taking action immediately after the issue was raised nationally by the Milwaukee outbreak, and treatment decisions were made prior to the issuance of any EPA rule.*

A related question is how especially sensitive populations should be protected. The effects on any given contaminant will vary by individual and by their health circumstances. Those with weakened immune systems due to cancer therapy, transplants or disease may be at a higher risk of infection from a given level of a pathogen than the general population. Lead exposure may be of more critical importance pregnant women and small children than others. Growing evidence links the risk of certain cancers to certain genetic factors. The setting of a safe threshold in a regulation or treatment decision must account for the variability of the population risk by establishing some margin of safety or other actions may be appropriate. The recent scientific debate over an appropriate maximum contaminant level for perchlorate focused extensively on what the targeted at-risk population should be. The policy conclusion by Massachusetts DEP was that the regulation should be protective of the most vulnerable. By contrast, EPA's regulations for the annual Consumer Confidence Report require the publication of specific language about the health risks of *Cryptosporidium* for those with compromised immune systems. Here the conclusion is that no water system could be expected to provide the extreme degree of protection that some might require, and that these individuals might have to take additional individual actions.

A recent example of perceptions creating consumer concerns has arisen recently in a number of communities converted to chloramines. MWRA has been using chloramines since the 1930's originally because it was an effective long lasting disinfectant for a large regional system, but more recently, many other systems have been switching from free chlorine to chloramine to reduce their disinfection byproducts. In many of those communities, citizens groups have sprung up concerned that the switch will cause a variety of health problems. While the science clearly seems to point to the switch reducing health risks, perception and the spread of rumor and supposition via the internet can provide a powerful counter narrative for citizens. Some MWRA customers contact the agency concerned that we might switch to chloramines, but generally are surprised to find that they have been drinking and bathing with chloraminated water for decades.

All of this relates to what our consumers expect of the water delivered to their taps. If asked, consumers will indicate that they want the water to be "safe". Unfortunately, there is no simple straightforward way of measuring "safety". As with all things in life, water cannot be delivered free of any risk to any individual. National policy decisions (as well as any local decisions) balance the degree of risk with the allocation of funds. Measured simply on the reduction of the risk from water, if disinfection is good, more disinfection is better, and more powerful disinfection and filtration is better still. Even better yet, two or three steps of filtration. Taken to the absurd, it is clear that there is some point where additional resources spent provide diminishing benefits, and that allocating those resources elsewhere make common sense. *MWRA's Integrated Water Supply Improvement Program and the treatment technology decision process balanced the investments in (and benefits derived from) treatment with additional resources allocated to community distribution systems, successfully arguing that a balanced investment profile yielded the largest benefits to consumers.*

5.10 Lead and Copper Rule

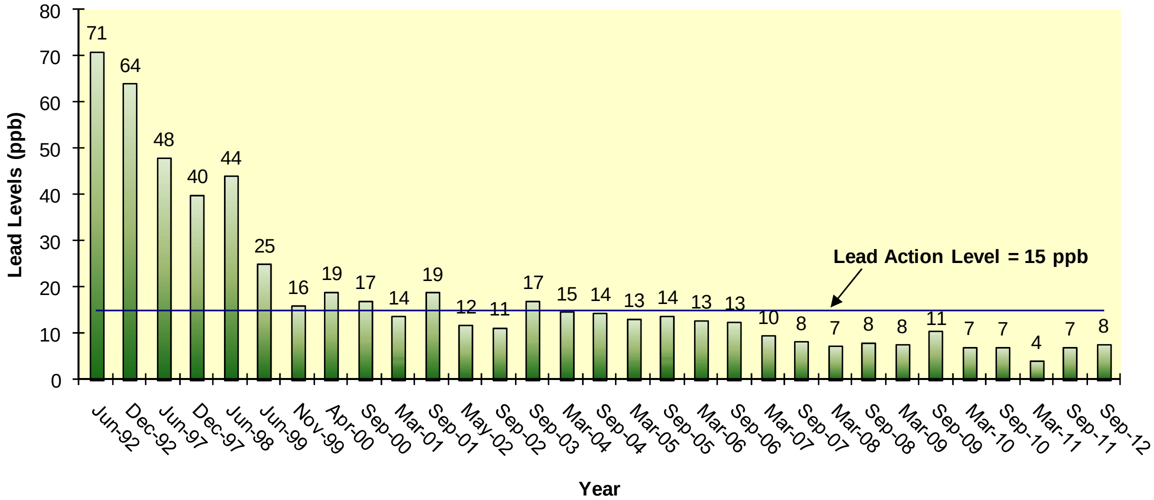
This rule is designed to reduce the risks of lead or copper being leached out of consumers' home plumbing and service lines by corrosive water. It is different than almost any other drinking water rule in that the water system does not control a large portion of the relevant physical assets. The rule requires that water systems sample for lead in certain homes, and depending on the results, provide corrosion control treatment to reduce the leaching of lead from home plumbing. In addition, if levels are above the Action Level, water systems may be required to undertake education efforts to inform their customers about lead, and to remove any lead service lines which may still exist.

The samples are not the usual samples that water systems are required to take of source water or of water as it leaves the treatment plant, but of stagnant water in individual homes. And not just any random homes or homes which are representative of average conditions within the service area, but homes which were judged by EPA to be of higher risk of having lead containing plumbing within the house, or in the service line under their front yards.

When testing began for this rule in 1992, the MWRA system had levels substantially above the action level of 15 ug/l. MWRA immediately began an aggressive education program and fast track design and construction of corrosion control. The plant went on-line in 1996 and treatment was fully ramped up by 1998. The Carroll Water Treatment Plant contains the same corrosion control processes. Lead levels have declined by about 80% as can be seen in the chart below.

System-wide lead results have been below the Action Level in each of the past sixteen sampling rounds. However, while results have dropped there is still the possibility that a relatively small number of samples with slightly higher results could result in exceeding the Action Level. There continues to be variability in the individual community results based on the small number of sampled sites and changes in individual volunteer sampling homes.

Figure 5-2
90th Percentile Lead Levels for
MWRA Fully-Served Communities: 1992-2012



Due to the small number of homes which continue to be above the Action Level, a number of communities have been required to do mandatory lead service replacement programs and mandatory lead education. *MWRA's goal is to continue to reduce the lead levels until no community has results above the action level. Reaching that goal may be difficult as MWRA's corrosion control treatment is very close to optimum according to our outside experts. This will be a continuing challenge as other treatment changes are made.*

At this point, no additional capital expenditures are recommended.

Recent national research has indicated that some portions of EPA's Lead and Copper Rule actions may not be providing the expected public health benefits, and it is expected that there may be substantial changes in the upcoming long term revisions to the LCR. The LCR requires that any system which is above the action level for lead and still has lead services undertake a mandatory program of removing those services at a rate of at least 7 percent per year. The expectation was that removing the lead service would reduce lead exposure from the drinking water, even if only the portion owned by the water system was replaced, leaving the portion on the homeowners property untouched. Recent studies do not support that expectation, finding that in the short term lead levels will rise after a replacement and that in the case of partial replacements, the levels often do not drop below the original level even after months. EPA has indicated that they expect to revise the lead service line replacement requirement, but the specifics and how ownership concerns and the need to do repairs or replacements during ordinary maintenance or other utility work in the street will be addressed are unknown. EPA is also considering changes to the sampling protocols which may have the effect of increasing the lead levels in sample results, such as requiring that all samples be at homes with lead services and that the samples be of water which has sat stagnant within the lead service itself. This may have the impact of increasing the risk of exceeding the action level.

If as a result of these changes, the MWRA system is above the lead action level, a comprehensive review of corrosion control treatment will be required, and potentially different treatment

chemistry would be required by both MWRA and perhaps the partial user communities. Changes in lead service line replacement requirements could require communities to develop funding methods to replace the privately owned portion of the lead service lines.
MWRA staff continue to be actively involved in research and with EPA regulatory development processes.

5.11 Simultaneous Compliance

An emerging issue of concern is the interaction of various rules. The interaction of disinfection to kill germs and the creation of undesirable byproducts of disinfection has been recognized for some time, but more recently it has become clear that almost all stages of treatment can potentially affect other compliance goals. The lead in drinking water debacle in Washington DC in early 2004 now seems to have been definitely related to inadequately considered changes in disinfection practice which dramatically and unexpectedly increased lead levels. Similar lead corrosion problems have been identified as potentially related to changes in coagulation chemicals in filtration plants, and one cause of the cryptosporidiosis outbreak in Milwaukee may have been a change in the type of coagulant to improve filter performance. EPA and treatment researchers are now looking carefully at a wide range of chances for improvements in one aspect of treatment or system operation to adversely affect other important goals.

In addition, subtle seasonal or longer term changes in source water quality may have unexpected effects on treatment effectiveness. For example, in the MWRA system, levels of certain more reactive natural organic matter (as measured by UV 254 absorbance) appear to affect the amount of lead leaching from home plumbing or decreases in chloramine residuals with community systems, even if all other aspects of treatment are unchanged. These changes can occur, not because of changes in watershed activities, but due to the relative contribution of "younger" Wachusett or "older" and better Quabbin reservoir water being delivered in wetter or dryer years. It is not yet clear if there are simple changes in treatment which could be used to adjust for these types of source water quality.

5.12 Source Water Quality and Watershed Protection

As indicated above, source water quality and watershed protection are key factors in maintaining MWRA's unfiltered status. Both are the responsibility of MWRA's partner agency the DCR. With the exception of land acquisition, almost all DCR's water quality related activities are essentially maintenance type activities and are accounted for within DCR's annual current expense budget.

For the purposes of treatment and regulatory compliance planning, this plan assumes that DCR will be able to continue its successful watershed protection efforts, that source water quality will be maintained within the filtration waiver criteria, and that both the CVA and MetroBoston systems will remain unfiltered[16].

16 The capital cost of adding the filtration components to the CWTP is roughly estimated to be $250 million, with annual operating costs of about $4 million per year, and of course, additional asset protection costs for all the additional process equipment and facilities.

The key issues in remaining unfiltered are likely to continue to:

- "Control of the Watershed"
- Source water quality (bacteria and turbidity) and
- Management of organics (UV254) as related to treatment.

Only one aspect of watershed protection falls within the capital budget framework: land acquisition. Under the new institutional arrangements created with the Watershed Trust, MWRA directly funds any DCR land purchases through the MWRA CIP. Protection of the watershed and source water quality through the control of the land within the watershed is one of EPA's yardsticks for measuring the effectiveness of a watershed protection plan. Over the past decade, many of the unfiltered systems have added filtration to their systems. As one of a shrinking group, it can be assumed that MWRA's watershed programs will continue to be under careful EPA scrutiny.

The SWTR includes the requirement that an unfiltered system "Gain ownership or control of the land within the watershed…for the purpose of controlling activities which will adversely affect the microbial quality of the water." As originally conceived by EPA in its guidance documents, a well protected watershed was one which was entirely owned and controlled by the water system.

Many of the west coast unfiltered systems achieve this standard or come close. Seattle owns essentially 100% of its watershed as does Portland Oregon. San Francisco's watershed is owned by the National Park Service, and is managed for protection of the supply. The eastern unfiltered systems generally have more fragmented ownership within their watersheds, and own less of the land. Even with 15 years of aggressive land acquisition, New York City still only owns only about than 13 percent of their 1,970 square mile watershed (with other state and local protected lands the total is still only 40 percent). Portland Maine only owns about 2 percent. The Quabbin, Ware and Wachusett watersheds have a combined DCR ownership of 43.6 percent. If lands protected by other local, state and non-profit groups are included, approximately 58 percent is protected. (If the areas where development is regulated by the Watershed Protection Act are included, the total rises to about 75 percent.) While it began with a standard of requiring 100 percent ownership or control, EPA does recognize the value of efforts to protect undeveloped land over time and the benefits of protecting higher value lands rather than simply owning more land.

In the protection plans approved by DEP to maintain MWRA's waiver of filtration, a continuing program of land acquisition is assumed without specifics on pace and scope. The MWRA/DCR approach has been to identify highest "value" critical lands and intercept them before adverse development occurs. The pace and scale of the program are linked to the ability to "stay ahead" of development which might adversely affect water quality. DCR's land acquisition plans (along with on-going regulatory activity under the Watershed Protection Act) focus on the need for an on-going commitment to preventing adverse development on critical lands through:

  - Support of good local community planning;
  - Use of Watershed Protection Act (Cohen Bill);
  - Purchase of conservation restrictions (CRs); and

- o The purchase of land in "fee simple" with the associated long term commitment to payments in lieu of taxes, only if necessary.

Purchases are expected to focus primarily on lands and activities likely to result in microbial contamination of the source water, with more limited focus on ease of management (reduction of fragmentation and boundary issues) and protection of continuous corridors. A critical issue for MWRA over the longer term will continue to be the payment-in-lieu of taxes (PILOT) on land that the DCR owns. Purchases of development rights or conservation restrictions do not create an obligation for PILOT payments and achieve substantially the same long term protection. Therefore there is a strong MWRA preference for having future land acquisition activities largely limited to conservation restrictions.

Figure 5-3

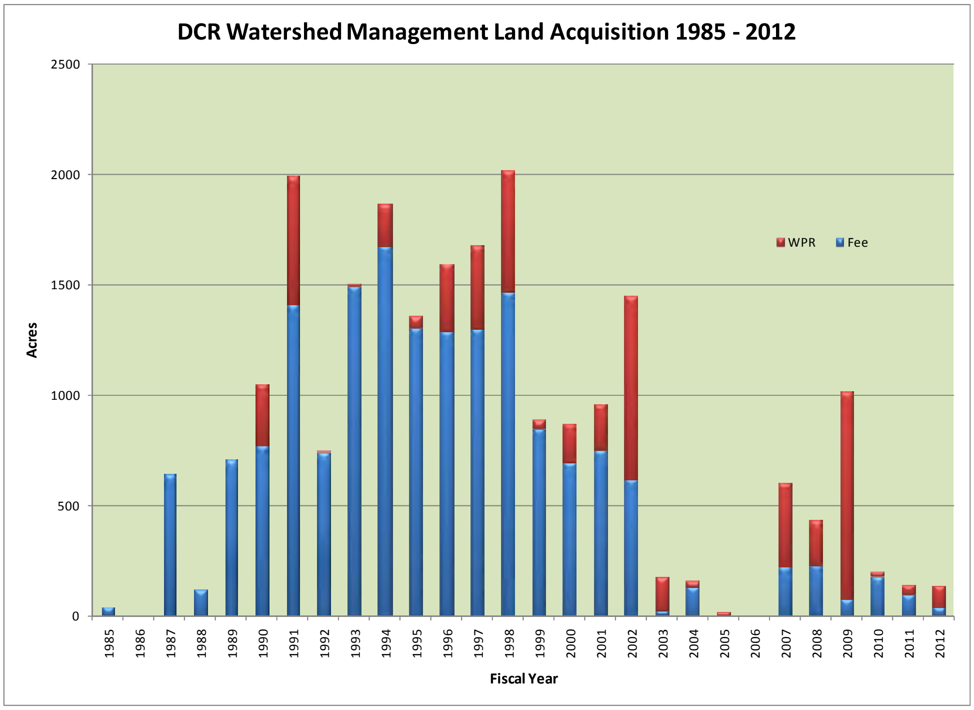


Table 5-3

Watershed	Total Watershed Area	Acres Owned 1985	Percent Owned 1985	Acres Owned 2012	Percent Owned 2012
Wachusett	70, 678 acres	5, 608	7.9	18,866	28.1
Ware River	61,737 acres	19,300	31.3	23,620	38.3
Quabbin	95, 466 acres	51, 792	54.3	55,965	58.6
TOTAL	**227,881 acres**	**76,700**	**33.7**	**99,452**	**43.6**

Opportunities to protect land typically come when the current owners desire to sell the land to retire or relocate. If the development rights or land are not purchased at the point in time, they will usually pass to a developer, and future protection opportunities will be more costly. Timing and the ability to respond to a particular owner's circumstances will continue to be critical to cost effective protection.

<u>Recommendation - Land Acquisition:</u>

- The FY14 CIP contains $1.5 million for FY14, with $6 million programmed from FY14-FY18

- *It is recommended that that an average of $1 to $2 million be allocated annually between FY2014 and FY2022 for the purchase of the most critical lands which are in danger of adverse development.* It is anticipated that these expenditures may not be uniform over time as the DCR takes advantage of opportunities as they arise to prevent degradation of water quality over the medium term (10-20 years). No recommendation is made for activities beyond that period.

Table 5-4

Water Master Plan - Watershed Land Acquisition

Existing and Recommended Projects

Last revision 9/23/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
5.01		Watershed Land Acquisition	AP	621	60081_7069	5 years	6,000	ongoing-FY18	6,000				6,000
		SUBTOTAL - Existing - Land Acquisition					**6,000**		**6,000**	**0**	**0**	**0**	**6,000**
5.02		Watershed Land Acquisition	AP	new		as needed	35,000	FY19-53		5,000	10,000	20,000	35,000
		SUBTOTAL - Recommended - Land Acquisition					**35,000**		**0**	**5,000**	**10,000**	**20,000**	**35,000**
		SUBTOTAL - Existing and Recommended - Land Acquisition					**41,000**		**6,000**	**5,000**	**10,000**	**20,000**	**41,000**

6 Water Treatment and Facilities

6.1 Chapter Summary

This chapter describes the existing treatment facilities put in place to meet regulatory requirements and customer expectations, outlines what will be required to maintain those facilities over time, and discusses what new facilities and modifications are being constructed to meet the new and expected regulations described in the previous chapter. The chapter deals first with the Carroll Water Treatment Plant serving metropolitan Boston and then with the Chicopee Valley Aqueduct system serving the three CVA communities.

The Master Plan recommends that:

To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should complete construction of Ultraviolet light disinfection at the Carroll Water Treatment Plant (CWTP) by April 2014. The new facilities constructed within the extended ozone contact chambers will provide the ability to comply with both the requirement for 99% inactivation of *Cryptosporidium* and the use of two primary disinfectants, and allow for the reduction of the ozone dose. The improvements are expected to cost approximately $36 million for design and construction.

To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should complete construction of Ultraviolet light disinfection at the site of the current chlorination facility (the Quabbin Water Treatment Plant, also known as the Ware Disinfection Facility) serving the Chicopee Valley Aqueduct communities at an approximate design and construction cost of $7.3 million.

The existing Carroll Water Treatment Plant requires certain ancillary modifications to optimize its performance and incorporate improvements from lessons learned over the first year of operation. These modifications and improvements are expected to cost approximately $ 6.7 million over the period FY09-15. Investments should be made to convert obsolete facilities at the CWTP and at Cosgrove Intake to provide expanded maintenance and storage space and permanent work space for the SCADA technicians.

Both the CWTP and the Quabbin Water Treatment Plant (QWTP) will require regular investments in asset protection to maintain them in proper working order. Based on the mix of long lived concrete facilities and shorter lived electrical and moving components, approximately $0.5 million is recommended in the FY16-17 period to initiate a long-term asset protection program for the CWTP with a placeholder value of up to $50 million until the study is complete and a more detailed analysis is available and similarly a $4 million placeholder is recommended in the FY27-33 time period for asset protection at the QWTP.

6.2 Current Treatment for Metropolitan Boston

The John J. Carroll Water Treatment Plant is the center piece of the Integrated Water Supply Improvement Program. When it went on-line in July 2005, it consolidated all treatment steps for the metropolitan area into one site at the junction of Marlborough, Southborough and Northborough, essentially at the western edge of the service area. The ozonation system at the plant was designed to achieve site-specific 99 percent inactivation of *Cryptosporidium*[1], at least 99.9 percent inactivation of *Giardia*, and at least 99.99 percent inactivation of viruses. The plant achieves the *Cryptosporidium* target, and regularly far surpasses required *Giardia* and virus targets.

The plant has a maximum day capacity of 405 million gallons per day. Water flows into the plant from the Cosgrove Aqueduct by gravity under all flow conditions, and passes through the plant to the MetroWest Tunnel and Hultman Aqueduct without pumping. As described in Chapter 7, work is underway to provide partial redundancy to the Cosgrove Tunnel by providing a pump station to lift water from the Wachusett Aqueduct into the CWTP. The plant is designed and operated as two parallel plants allowing for half plant operations during low flow months for system maintenance and upgrades. The 45 million gallon storage tank is also able to be isolated in two parts for cleaning or maintenance. Pumping is provided at the CWTP for internal plant use and for Northborough and Westborough State Hospital.

The plant generates ozone on-site for primary disinfection using purchased liquid oxygen (LOX) and four 3,380 pounds per day ozone generators. The generators can be used in various combinations to feed ozone into four ozone contact chambers. These concrete "under and over" baffled chambers allow the water to be ozonated in several locations, and for measurements of the residual ozone to be made at several points.

The ozone generators are power intensive, and require high quality power. Interruptions, even for less than a second, can cause the ozone generators to shut down. The plant has been modified to stay in operation for very brief periods of ozone generator shut down, but if the outage extends beyond five minutes the plant shuts down and must be restarted. Plant operating procedures prevent untreated water from being sent to consumers. Ozone gas is extremely hazardous and the plant provides negative pressure in the contactors through ozone destruct units. If ozone gas is detected above safe levels in the area above

1 The 99 percent or 2-log inactivation is a voluntary operating target for plant operations. It is based on site specific testing infectivity studies of ozone disinfected water. As discussed later, it was not designed to provide treatment meeting the new more stringent requirements of the LT2ESWTR, as this rule was issued after the design was completed.

the contactors, the ozone generators automatically shut down which will cause the plant to shut down. Pressure fluctuations within the Cosgrove tunnel caused by any sudden change in flow through the Cosgrove Intake and Power Station can cause vacuum changes and thus cause the ozone units to shut down. With operators trained in procedures for restarting the plant, and the onsite storage in the 45 million gallon clear well and at the 115 million gallon Norumbega Covered Storage Tank, no service disruptions have resulted due to plant interruptions and shut downs.

The plant has full back-up power capability with four 2,000 KW diesel generators. These are used when line power is down and to avoid a plant shutdown if a power interruption seems likely, and can be used to reduce demand charges and as part of utility demand response programs reducing the cost of electricity.

Once the water is ozonated[2], it receives corrosion control, is fluoridated, and chloraminated for residual disinfection. Corrosion control involves raising the alkalinity with sodium carbonate, and adjusting the pH with carbon dioxide. Chloramination involves first adding chlorine (sodium hypochlorite) and then after a short contact time, adding ammonia to form monochloramine.

The CWTP is the Operations Control Center (OCC) for the entire treatment and transmission system. The treatment and transmission operators on duty are responsible for operations from Shaft 5 of the City tunnel in Weston all the way to the CVA system treatment and storage facilities in Ware and Ludlow. The plant control room is connected via SCADA to all Western Operations facilities.

The CWTP OCC also includes duplicate equipment to serve as a back-up for the metropolitan operations control center for both water and sewer functions if the Chelsea OCC is unavailable. An emergency operations center (EOC) in the training room of the CWTP operations building serves as a back up to the Chelsea EOC as well. Critical MIS functions will also have back up capability at the CWTP to ensure continued operations if the Chelsea MIS center is inoperable.

The plant is normally operated by a minimum of 3 operators per shift. During the day shift, additional operators and management staff are present, as well as maintenance staff. During off shifts, the operators also manage the CVA treatment facilities in Ware, and if available, one of the operators may perform off-site monitoring rounds.

The plant is extensively automated for both operations and regulatory compliance. Monitoring of raw water quality occurs both at the Cosgrove Intake at Wachusett Reservoir several hours upstream of the plant, and at the plant inlet. Treatment parameters are tracked throughout the process for calculating regulatory compliance and for process control feedback.

2 As is discussed below, as originally designed and constructed, there were additional ozone contact chambers which are now being used to house the UV treatment facilities.

Monitoring instrumentation requires regular maintenance and calibration if it is to be relied on for process control and compliance. Instrumentation and electronic control equipment must also be supported by the manufacturer, and may become obsolete if the manufacturer no longer supports it with maintenance, updates and spare parts. The asset management placeholder assumes that SCADA software and hardware need regular updating on a schedule of every 5 to 10 years.

Table 6-1 JJCWTP Treatment Process Control Instrumentation

Parameter	Purpose	Number of Instruments
Temperature	Compliance and Process Control	6
pH	Compliance and Process Control	11
Turbidity	Compliance	2
UV 254 Absorbance	Process Control and Source Monitoring	1
Ozone Residual	Compliance and Process Control	20
Ozone Ambient Air	Worker Safety	20
Sulfur Dioxide Ambient Air	Worker Safety	2
Oxygen Ambient Air	Worker Safety	4
Chlorine Ambient Air	Worker Safety	2
Ammonia Ambient Air	Worker Safety	2
Carbon Dioxide Ambient Air	Worker Safety	4
Pressure	Process Control	51
Level	Process Control	57
Free Chlorine	Process Control	2
Total Chlorine	Process Control and Compliance	4
Conductivity	Process Control	1
Oxidization Reduction Potential	Process Control	4
Fluoride	Compliance and Process Control	4
Particle Count	Source Monitoring	2
Flow Metering	Process Control and Compliance	70
Flue Gas NOx	Process Control and Compliance	4
Dewpoint	Process Control	4
Oxygen Percent	Process Control	4
Ozone Gas Concentration	Process Control	10
Contaminant Monitoring System	Security	1

The completion of the UV disinfection facility will add a substantial number of additional instruments and additional SCADA equipment to the plant, with the associated need for maintenance and long term asset protection.

6.3 Asset Management and Ancillary Modifications to the Existing CWTP

It is typical for all major new facilities to have a several year period of plant familiarization, optimization and customization as plant staff learn the intricacies of plant operations and maintenance under a variety of conditions. The lessons learned from this period of familiarization are distilled into a series of “ancillary modifications” to the plant to optimize operations, facilitate maintenance, and achieve efficiencies in operating.

A series of plant improvements and evaluations have been undertaken under this process.

1. Liquid oxygen is stored in three separate storage tanks. The liquid is converted to gas in the vaporizers and then piped to the Ozone Building through two separate 4-inch diameter stainless steel pipes. The two pipes were combined into a single pipe in the Ozone Building. This single pipe carried all the oxygen to the ozone generators. Failure of this pipe would have disrupted plant operation. A second oxygen feed pipe was constructed to provide redundancy in oxygen supply piping.

2. Vacuum relief valves were installed over the effluent channel in the Ozone Building to address high vacuum conditions that can occur during rapid flow changes. Positive pressurization also occurred during certain flow conditions. As discussed above, both conditions can result in plant shutdowns. Positive pressurization results in ozone release inside the work space of the plant which has worker safety implications. The larger the release, the longer it takes to clear the area and allow restart of the plant. Modifications to the pressure relief valves and piping were constructed to allow positive pressure to be released outside the building, thereby limiting worker exposure to ozone, and allowing for quicker plant restart.

3. The Wachusett Aqueduct is the emergency water supply conduit to the metropolitan Boston area in the event that the Cosgrove Intake or Tunnel is damaged or taken out of service. In order to meet sanitary conditions, the Wachusett Aqueduct cannot be connected “live” to the plant; some type of physical separation is required during normal operations to prevent a possible cross connection. This was initially achieved by the removal of a six-foot long piece of 120-inch diameter pipe and capping the pipe ends. Reactivation of the Wachusett Aqueduct would require the removal of the two 120-inch diameter flange caps and the insertion of a 6-foot long spool piece, taking approximately two days. Recently completed construction of valves to be installed on this pipe will allow for a rapid transition to the Wachusett Aqueduct, while still achieving an acceptable sanitary air gap between raw water supply piping and the plant during normal operations.

   It is important to note that, as discussed in the Chapter 7, the flow from the Wachusett Aqueduct is only able to meet winter time demands; and that it currently would require chlorine treatment at the reservoir because the flow passes below the CWTP process elevations and cannot be ozonated. Construction of the Wachusett Aqueduct Pump Station will allow the full capacity of the Aqueduct to be treated at the CWTP. This will provide the ability to supply approximately 230 million gallons per day and allow the potential for shut down of the Cosgrove Aqueduct or Intake during the lower demand portions of the year.

4. The plant receives frequent (8 to 9 per week) deliveries of commercially produced liquid oxygen, and a delay in deliveries could interrupt treatment. A study has recommended providing additional liquid oxygen storage and more flexible supply piping as a way to achieve additional reliability. Adding one or two additional liquid oxygen storage tanks would provide 3 or 6 days of additional storage at a cost of $1 to 1.5 million dollars.

5. The ozone generators were initially cooled with raw water. An open-loop system was selected during design as it has a lower operating cost than a closed-loop system. Premature fouling of the generator sleeves and subsequent corrosion of the stainless steel sleeves and plate were discovered due to biological growth in the generators. A closed-loop cooling system was designed and installed to circulate cooling water through heat exchangers. This has provided for more certain control of cooling water quality.

6. Concrete condition monitoring in all chambers has indicated incipient failure of expansion joints in the ozone contact chambers due to harsh conditions. Repair work will likely be done in stages over several years as part of annual winter maintenance while half the plant can be removed from service, and thus will likely be funded out of the CEB.

7. Security to the entrance of CWTP has been improved to prevent access to the plant by unauthorized vehicles and also to document the number of people at the facility, including cameras to document activity at the entrance. Additional security measures, partly funded by a federal grant, and a covered entrance to help concentrate lighting and provide weather protection for security staff is under design.

It is expected that additional potential modifications will be identified over the next several years of operations and maintenance and these will be incorporated into later ancillary modifications to the plant. Approximately $6.7 million is recommended over the period FY09-15.

All facilities require regular investments over the long term to maintain them in good working order. While the concrete and major piping of the CWTP should provide good service for 50-100 years, much of the operating equipment can be expected to need replacement or refurbishment after providing service on the order of 10 to 20 years. The plant has substantial electrical and mechanical systems which will likely require replacements/upgrades starting at a 10-year life. It is anticipated that the SCADA software and hardware will need to be replaced within the next 5 to 10 years.

Certain equipment is operated on a continuous basis and experiences severe duty, such as the sluice gates and valves that provide continuous hydraulic control for the plant and which control application of chemicals for treatment processes. Replacement of these types of equipment is difficult as plant by-pass or complete shut downs may be required. Based on condition inspections, it is anticipated that the sluice gates within the post treatment building which have experienced accelerated aging due to ozone exposure may have a useful life of only 10 to 20 years rather than the more typical 50. Replacement cost is estimated to be approximately $1 million.

Other equipment, such as chemical storage tanks, ozone generators, and the plant water system, were installed and the building construction was completed around them. This sets up the potential for difficult future replacement projects toward the end of the equipment life. The ozone generators are expected to have a useful life of about 20 additional years, assuming a “rebuild” every ten years at a cost of $1 million. An evaluation of whether it is possible and advisable to “derate” the ozone generators after the UV disinfection is operational is recommended. Lowering the capacity of some of the generators would allow improved operational flexibility, and potentially reduce ozone operating costs during low flow periods without sacrificing reliability.

The soil on the top of the covered storage tank has been found to be less permeable than required, causing ponding of water above the water storage facility, and hindering drainage of rainwater. This is an unacceptable condition, as it increases the risk for leakage of stormwater into the finished water tank, potentially compromising its sanitary protection. In addition, MWRA has improved its design approach to the waterproofing and drainage system on subsequent covered storage tanks, reducing the risk of water intrusion. The soil must be removed and replaced with suitable material, and the waterproofing replaced. An initial portion of the work is being done on the roof over the UV area. The remaining portion of the work is expected to be constructed during 2014 at an estimated cost of $ 4.1 million.

It is impossible to predict which specific systems, non-equipment assets, and equipment will need replacing at any point in the future. However, it is prudent to expect that a percentage of the assets will need replacing, and that significant efforts will be required to replace some of them after 20 years of service. Good planning for such replacements should include a regular process for project identification and prioritization along the lines of the model being developed by the MWRA’s asset replacement task team. By the end of this Master Plan’s planning horizon, portions of the CWTP will be almost 50 years old, and even the new UV equipment will have been in service for 40 years.

Based on the mix of assets at the CWTP, MWRA should expect to invest approximately $0.5 million in FY16-17 to initiate a long-term CWTP asset protection program currently assumed to represent an investment of up to $50 million over the period FY19-53. That placeholder estimate will be refined based on the asset protection study.

6.4 Required Changes Underway to Meet New Stage 2 D/DBP and LT2ESWTR Requirements - Carroll Water Treatment Plant

As discussed in Chapter 5, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which was promulgated in January 2006, requires that MWRA add an additional disinfectant at the John J. Carroll Water Treatment Plant (CWTP) and at the Quabbin Water Treatment Plant (QWTP) serving the Chicopee Valley Aqueduct (CVA) communities. Under the new rule, all unfiltered systems must have two primary disinfection systems[3], one capable of achieving 99.9 percent *Giardia* and 99 percent *Cryptosporidium* inactivation and the other capable of 99.99 percent virus inactivation. Based on the findings of pilot testing and other research, ultraviolet (UV) light disinfection was determined to be MWRA's most cost-effective solution at both locations.

Compliance with LT2ESWTR is required by April 2014 for the CWTP as DEP has granted the statutorily available two-year extension for plants requiring substantial capital modifications. (Compliance for the CVA system will be 6-months later, as it serves less population.) Design has been completed and construction at the CWTP is underway and on schedule to meet the regulatory deadline.

Recent developments with UV technology make it an attractive disinfectant alternative for use as a second primary disinfectant for both the CWTP and the QWTP. UV disinfection uses intense light energy to disrupt or alter the DNA of a microorganism rendering it incapable of reproducing and thus causing illness. UV has recently emerged as an effective disinfectant for *Cryptosporidium*. The benefits that UV disinfection offers as compared with other disinfectants are:

- No known production of disinfection by-products;
- No known increased risk of re-growth in the distribution system;
- Lower capital and operational costs than ozone; and
- Higher effectiveness for inactivation of *Cryptosporidium* at cold temperatures than with ozone.

Treatment Process Evaluation - CWTP

In 2006, staff recommended, and the Board of Directors approved, proceeding with a sequential process of ozone, UV and chloramine for the CWTP in order to comply with the new regulations. It is expected that this treatment process will result in a reduced ozone dose, reducing the potential for bacterial regrowth within the distribution system and reducing energy and liquid oxygen costs. Ozone would continue to increase the clarity of the water; remove certain algae-related tastes and odors; and would also provide the required second primary disinfectant.

That recommendation was based on a review of three other alternative treatment processes:

<u>Ozone, Free Chlorine and Chloramine</u> - Free chlorine could be used to provide a second primary disinfectant. However, this would require that the CWTP ozone system be used for *Cryptosporidium* disinfection using the much more conservative inactivation

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3 Primary disinfection inactivates pathogens (harmful germs) in the source water. Residual disinfection is used to maintain the quality of the water as it passes through the distribution system.

requirements of LT2ESWTR[4], and that higher doses of free chlorine be used. The result would be an increased risk of distribution system bacteria growth and significantly higher disinfection byproducts, potentially risking compliance with the new Stage 2 Disinfectant/Disinfection Byproducts Rule.

<u>Ozone, Chlorine Dioxide and Chloramine</u> - Chlorine dioxide has been found to be effective in inactivating *Cryptosporidium* in warm, high pH waters. However, its effectiveness drops substantially in cold water to the point that chlorine dioxide would not be feasible at CWTP for the inactivation of *Cryptosporidium* and there are concerns about disinfection byproducts.

<u>Ozone, Filtration and Chloramine</u> - The addition of filtration facilities to the CWTP would eliminate the requirement for a second primary disinfectant and allow a lower ozone dose. However, the construction and operating costs of this alternative were far greater than for an ozone-UV facility. Based on staff's analysis of new federal regulations and the progress made to date in watershed protection, staff continue to see no current reason at this time to recommend any modifications to the original 1998 treatment technology decision to remain an unfiltered water system. The capital cost for this alternative would be more than $250 million.

The UV treatment units are being installed within the extended ozone contactors in the storage tank. The extended ozone contactors were added to the design of the CWTP in order to increase contact time to meet the site-specific *Cryptosporidium* inactivation criteria that were established after plant design had started. This contactor volume will not be required after UV treatment is added for *Cryptosporidium* inactivation, thereby making this space available for the UV reactors. This location was chosen because it would:

- Not preclude later addition of filtration;
- Minimize the value of facilities that would be rendered obsolete if filtration were later added;
- Take advantage of the fact that UV disinfection is more effective after ozonation than before;
- Maximize the effectiveness of ozone treatment during construction; and
- Minimize the reduction in storage within the storage tank.

4 As discussed in a March 8, 2006 staff summary, while MWRA designed the CWTP prior to the issuance of the LT2 using site specific inactivation data, EPA used much more conservative national data in developing the table or required CTs in the new rule. While MWRA is inactivating 99 percent of any *Cryptosporidium* in our water, we cannot take credit for that under the new rule, without substantially increasing the ozone dose.

Figure 6-1 Location of UV Treatment at CWTP

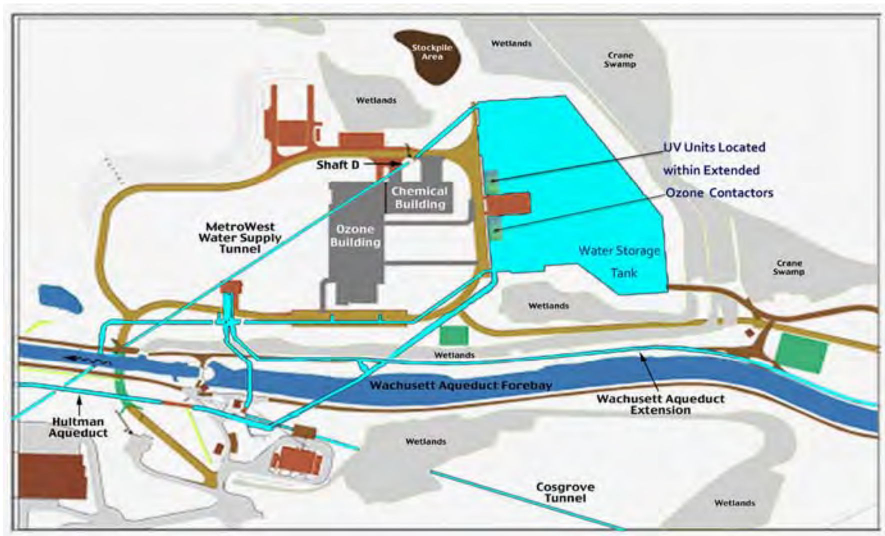
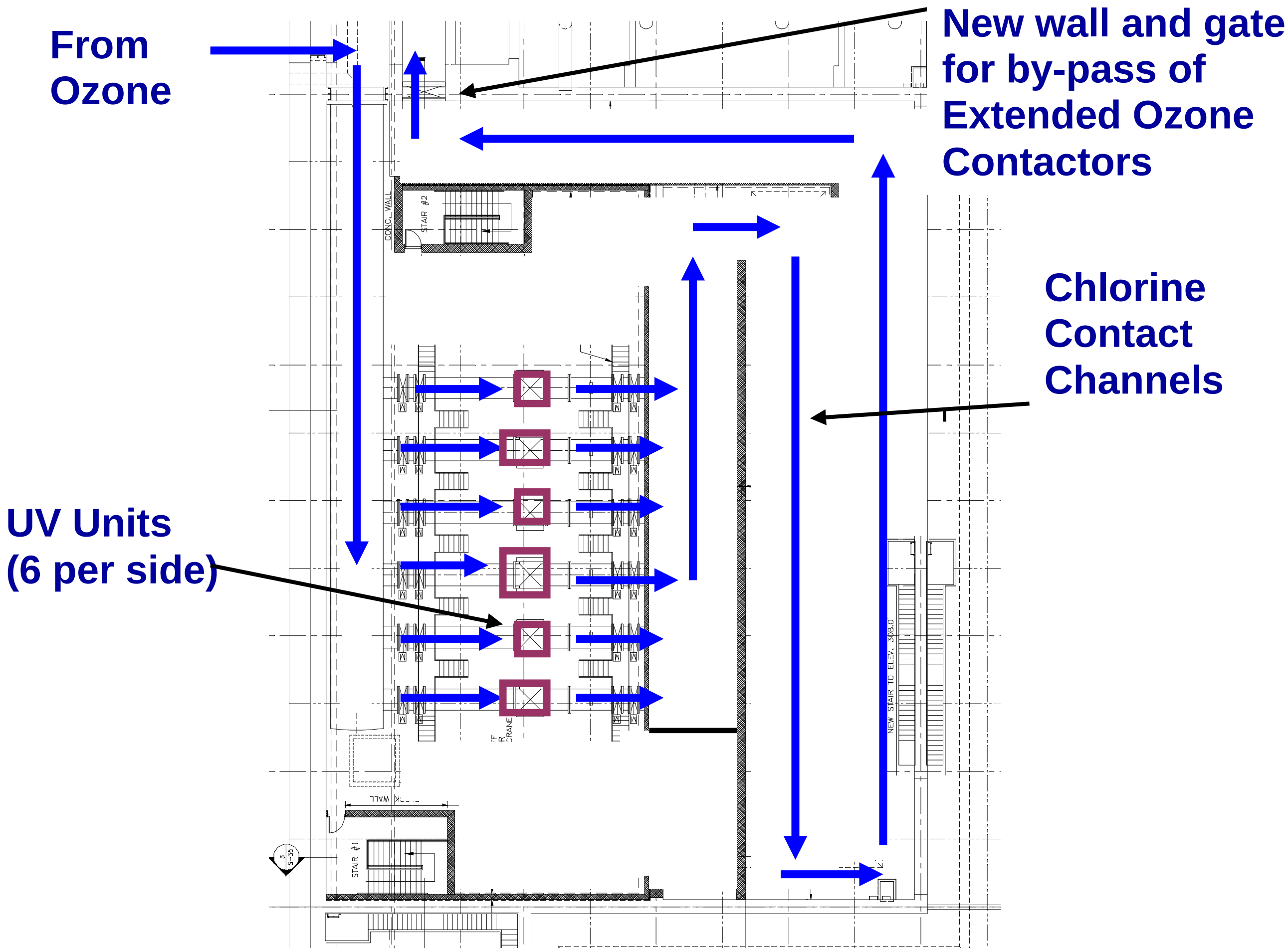


Figure 6-2 – Layout of UV Disinfection

Figure 6-3

UV Reactors and Chlorine Contact



Schedule and Cost

Construction is anticipated to be completed prior to the regulatory deadline of April 2014. Testing of the UV units began in September 2013. The estimated cost for design is $4.4 million; the estimated construction cost is $32 million. These funds are included in the Final FY14-16 CIP.

6.5 Current Treatment for the Chicopee Valley Aqueduct System

The Quabbin Water Treatment Plant provides primary and residual disinfection for the Chicopee Valley Aqueduct (CVA) system serving the three communities of Wilbraham, Chicopee and South Hadley Fire District No. 1. The facility, placed into service in 2000, is located adjacent to the CVA and the Swift River just north of Route 9 in Ware. The facility replaced interim disinfection facilities and allowed Wilbraham and South Hadley Fire District #1 to discontinue their chlorination facilities. Due to its location downstream of the Nash Hill Tanks, and larger distribution system, Chicopee still needs to provide booster disinfection at their entry point to maintain an adequate chlorine residual to the ends of their system. Each community also provides their own corrosion control treatment.

The facility has a maximum day capacity of 25 million gallons per day. It consists of chemical injection equipment to inject sodium hypochlorite (chlorine) into the CVA as well as process monitoring equipment. The travel time between the addition of chlorine and a monitoring location in Ludlow ("the Ludlow Monitoring Station" or LMS) provides the necessary contact time to meet the required CT values for 99.9 percent *Giardia* inactivation and 99.99 percent virus inactivation, meeting current Surface Water Treatment Rule requirements. Process monitoring includes monitoring for pH, temperature, turbidity, UV absorbance, and chlorine residual.

The facility is highly automated and can be monitored and controlled remotely via SCADA. The QWTP is staffed a single shift each day, and monitored and controlled remotely from the CWTP during off shifts. Day shift is two operators.

Table 6-2 QWTP Treatment Process Control Instrumentation

Parameter	Purpose	Number of Instruments
Temperature	Compliance and Process Control	4
pH	Compliance and Process Control	3
Turbidity	Compliance	1
UV 254 Absorbance	Process Control and Source Monitoring	1
Pressure	Process Control	2
Level	Process Control	4
Free Chlorine	Process Control and Compliance	3
Conductivity	Process Control	1
Flow Metering	Process Control and Compliance	5
Contaminant Monitoring System	Security	1

6.6 Asset Management for the Existing QWTP

The assumptions which lead to planning for periodic asset replacement at CWTP are similar for QWTP. Most of the equipment is not subject to the kind of physical or operating constraints as equipment at CWTP and subsequently a smaller percentage of total replacement cost funding can be assumed. A recommendation is included that up to $4 million be allocated for long-term asset management at the QWTP. Expenditures would be primarily in the FY27-33 time period. Most of the facility will have been in service for over 50 years by the end of the planning horizon. Project identification and prioritization procedures should be the same as for CWTP, with an initial asset protection study to define long-term needs.

6.7 Required Changes Underway to Meet New Stage 2 D/DBP and LT2ESWTR Requirements - Quabbin Water Treatment Plant

When the QWTP was designed, it was recognized that EPA would eventually issue new rules and that those rules would probably require some level of *Cryptosporidium* inactivation. At that time, only ozone appeared to be capable of inactivating *Cryptosporidium.* As the requirements were unclear, a life cycle analysis was done on whether it was cost effective to defer construction of the ozone plant until the rules were issued. In 1995, based on the life cycle cost analysis, MWRA delayed a decision on adding ozone at a cost of $15 million until the new rules were issued.

In 2006, staff recommended and the Board of Directors approved UV as the least expensive option for the CVA system. This is the most cost-effective solution as the UV facilities could be added in essentially the same location as originally designed for the ozone expansion. Staff recommended UV, chlorine and potentially chloramine for the QWTP in order to comply with the new regulations. The continued use of free chlorine as primary disinfectant at QWTP is possible due to the exceptionally low amount of organic materials in the raw water, thereby resulting in lower disinfectant byproducts. Staff anticipate that the levels of disinfection byproducts should be below the levels required under the Stage 2 Disinfectants and Disinfection Byproducts Rule, but will reserve the ability to add chloramine if additional DBP monitoring indicates that it is required[5].

The recommendation was based on a review of only one other treatment alternative:

<u>Ozone and Free Chlorine</u> - During the design of the QWTP, staff anticipated the future possibility of the need for addition of a stronger disinfectant, and the original design allowed for expansion with ozone. Ozone/chlorine would be substantially more expensive than UV/chlorine/chloramine.

<u>Filtration</u> was not considered given the higher level of protection and lower level of organic material in the Quabbin Reservoir source water, and its higher construction and operating costs.

The UV treatment units will be added in an addition to the QWTP upstream of chlorine injection to maximize system efficiency and to minimize lamp sleeve cleaning and maintenance requirements. The site plan of the existing QWTP and the design for the UV/chlorine/chloramination facilities is shown in Figure 6-4 below.

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5 The highest DBPs are expected to be at the ends of the Chicopee system. If the DBP levels are higher than the new regulatory standards or too close for continued reliable compliance, the addition of chloramine for the entire CVA system will be evaluated, as will the possibility of just chloraminating the Chicopee system at their existing treatment plant at the entry point to their system. Due to the complex water chemistry, the varying corrosion control strategies and the possible need to MWRA to adjust pH and alkalinity to properly chloraminate, the Chicopee solution may be simpler from a process control basis, and significantly less expensive.

Figure 6-4 Existing Quabbin Water Treatment Plant and Proposed UV/Chlorine/Chloramination Facility

Schedule and Cost

Construction is underway and expected to be completed prior to the compliance deadline of October 2014. The estimated design cost is approximately $1.8 million; the estimated construction cost for the facility is approximately $5.5 million. These funds are included in the Final FY14-16 CIP.

6.8 Recommended Actions and Future Capital Improvements

- To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should complete the addition of Ultraviolet light disinfection at the Carroll Water Treatment Plant (CWTP) by April 2014. The new facilities are being constructed within the extended ozone contact chambers, will provide the ability to comply with both the requirement for 99% inactivation of Cryptosporidium and the use of two primary disinfectants, and allow for the reduction of the ozone dose. The improvements are expected to cost $36.4 million for design and construction.

- To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should add Ultraviolet light disinfection at the Quabbin Water Treatment Plant serving the Chicopee Valley Aqueduct communities. This facility will be constructed at the site of the current chlorination facility at a cost of $7.6 million for design and construction.

- The existing Carroll Water Treatment Plant requires certain ancillary modifications to optimize its performance. These modifications and improvements are expected to cost approximately $6.7 million over the period FY09-15. Modification of obsolete facilities for maintenance, storage and SCADA staff use are expected to cost $1.6 million. Replacement of the storage tank roof drainage system is expected to cost $4.1 million.

- Both the CWTP and the QWTP will require regular investments in asset protection to maintain them in proper working order. Based on the mix of long lived concrete facilities and shorter lived electrical and moving components, approximately $0.5 million is recommended in the FY16-18 period to initiate a long-term asset protection program. An investment of $50 million is expected to be required for the CWTP in the FY16-53 time period. An initial $0.5 million was added to the FY14 budget. For the QWTP, $4 million is recommended in the FY27-33 time period.

Table 6-3

Water Master Plan - Water Treatment and Facilities

Existing and Recommended Projects

Last revision 9/30/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
6.01	2	Carroll Water Treatment Plant Storage Tank Roof Drainage System	Opti	542	53470_7376	1 year	4,066	FY15	4,066				4,066
6.02	2	Technical Assistance 7 & 8	Opti	542	75530_7406 75531_7407	3 years	1,126	FY14-16	1,126				1,126
6.03	4	Wachusett Algae - Design and Construction	NF	542	53428_6671 53448_6889	4 years	2,250	FY16-19	2,171	79			2,250
6.04	2	Carroll Water Treatment Plant Ultraviolet Disinfection - Design	NF	542	53450_6923	3 years	1,678	ongoing-FY16	1,678				1,678
6.05	2	Carroll Water Treatment Plant Ultraviolet Disinfection - Construction	NF	542	53451_6924	2 years	2,229	ongoing-FY15	2,229				2,229
6.06	2	Existing Facility Mods - CP7 - Design & Construction	Opti	542	53453_6951 53426_6650	3 years	6,661	ongoing-FY16	6,661				6,661
6.07	2	Ancillary Modifications - Construction 2	Opti	542	53457_7085	3 years	1,641	FY14-16	1,641				1,641
6.08	3	Carroll Water Treatment Plant Asset Protection	AP	542	75546_7455	2 years	500	FY16-17	500				500
6.09	2	Quabbin Water Treatment Plant Ultraviolet Disinfection - Design	NF	543	53439_6775	3 years	739	FY14-16	739				739
6.10	2	Quabbin Water Treatment Plant Ultraviolet Disinfection - Construction	NF	543	53440_6776	2 years	4,290	FY14-15	4,290				4,290
		SUBTOTAL - Existing - Water Treatment and Facilities					**25,180**		**25,101**	**79**	**0**	**0**	**25,180**
6.11	3	CWTP - Asset Protection	AP	new		ongoing	49,500	FY19-53		7,500	15,000	27,000	49,500
6.12	3	QWTP - Asset Protection	AP	new		6 years	4,000	FY27-33			4,000		4,000
		SUBTOTAL - Recommended - Water Treatment and Facilities					**53,500**		**0**	**7,500**	**19,000**	**27,000**	**53,500**
		SUBTOTAL - Existing and Recommended - Water Treatment and Facilities					**78,680**		**25,101**	**7,579**	**19,000**	**27,000**	**78,680**

7 The Transmission System

7.1 Chapter Summary

The transmission system consists of over 100 miles of tunnels and aqueducts in daily use which transport water by gravity from the supply reservoirs to points of distribution within the MWRA service area as well as back-up facilities for use in emergencies. The transmission system has evolved over time in response to increased population, expansion of the service area and the need to go farther from developed areas for adequate and high quality sources of water. This system was designed in such a way that the basic layout remains fundamentally sound and useable. The performance standards required to be met by a major transmission system are twofold. The system must be able to transport sufficient water to meet the maximum daily demands of the service area. Secondly, the system must be reliable in that it must have sufficient redundant components to ensure a continued supply of water if any single "leg" of the system were to fail or needed to be taken off-line for maintenance or rehabilitation.

The 2006 Water System Master Plan contained a number of recommendations for transmission system improvements. The major recommendations addressed the need to continue to develop solutions to identified short-falls in system redundancy. The 2006 plan noted that, in the interim, system improvements over time have allowed for older facilities, no longer in daily use, to remain as critical emergency standby facilities as long as maintained and linked to new facilities where necessary. The importance of this was demonstrated in May 2010 (May 1-4, 2010) when a coupling gave way on a 120-inch diameter connecting pipe adjacent to Shaft 5A where the MetroWest Water Supply Tunnel meets the City Tunnel. This catastrophic leak resulted in an immediate need to shut-down and re-direct flow to the Metropolitan area. Adequate flow and pressure for all uses was maintained throughout the incident. A precautionary boil order was put in place as the Sudbury Reservoir system, the Sudbury Aqueduct, the Chestnut Hill Reservoir and the Chestnut Hill Emergency Pump Station were all activated. Preparations were also made to activate the Spot Pond Reservoir if necessary.

The initial break took place on May 1st and on May 3rd, the repairs were completed and the line pressurized and put back into service. Extensive coliform testing within the communities allowed the lifting of the boil order on May 4th. MWRA worked extensively with the Governor's office, DEP and many other agencies through the Massachusetts Emergency Management Agency to mitigate the effect of the break.

At the time of the break, rehabilitation of the Hultman Aqueduct was underway, including additional interconnections between the Aqueduct and the MetroWest Water Supply Tunnel (MWWST). This project ultimately allows the seamless transfer of water between those two facilities increasing the water system redundancy and operational flexibility. In addition, in 2008, MWRA initiated Concept Planning to address redundancy shortfalls for the Cosgrove Tunnel and for the Metropolitan Tunnel System including the City Tunnel, City Tunnel Extension and the Dorchester Tunnel.

The ability to maintain flow and pressure for fire protection, sanitation and, with the precaution of the boil order, all other household uses demonstrated the value of redundancy. The implementation of the emergency measures and the cost of the boil order demonstrated the need for redundancy that allows fully potable water to be delivered. This “lesson” has been a factor in long-term redundancy planning subsequent to this event and will be fully discussed later in this chapter.

The events of May 2010 confirmed the need to move expeditiously forward with redundancy planning, design and construction. But, it also underscored the fact that while failures of the actual tunnels may be of relatively less concern, failures of connecting pipes, valves or other appurtenant structures of the tunnel system could have the same system impact. Clearly, the goal of the redundancy planning is to allow the seamless transfer to the redundant systems without a disruption in the supply of potable water. However, maintaining the older stand-by facilities for emergency use if needed will continue to be a component in MWRA’s ability to respond to a range of operational or emergency disruptions.

This chapter will provide an update on redundancy work undertaken or completed since 2006 and will address the remaining goals to be accomplished. In addition to redundancy improvements, it will summarize recently completed, ongoing and recommended work to rehabilitate and improve Western Operations facilities to ensure their long-term reliability. There has also been a significant increase in identified and completed work to ensure dam safety since 2006 and substantial information is also provided on status and future recommendations.

The organization of this chapter is generally focused on the assessment of the transmission system in terms of both its physical condition and an assessment of how well it meets the goals for reliability, including redundancy. The components of the system that operate under normal conditions are discussed first, organized for discussion geographically, beginning at the Quabbin Reservoir and moving through facilities and structures to the eastern part of the system. Following the discussion of active facilities, the portions of the system that are not in daily use and that are maintained for emergency use, are discussed. Dams are discussed separately in Section 7.6 followed by a Summary of Recommended Improvements in Section 7.7.

Summary of Chapter Recommendations

In the near-term, the Master Plan identifies approximately $313 million in transmission system project needs for the FY14-23 timeframe, including all projects currently in the FY14 CIP as well as recommended projects. Implementation of UV technologies at the CWTP and at the Quabbin facility are not included below and are discussed in Chapter 6.

<u>Transmission System Projects already in the FY14 CIP</u>**:**

For the FY14-23 timeframe, the FY14 CIP includes most notably the following transmission system projects:

- As noted above and further explained in Section 7.4, transmission redundancy is a major part of the current CIP with approximately $318 million allocated to the southern part of the long-term redundancy solution for the Metropolitan tunnels and approximately $50 million allocated for Cosgrove Tunnel redundancy through construction of a pump station. Pump Station design work has begun and additional concept refinement and MEPA review for the southern section also began in 2012.

- A project has also been added to the CIP to address rehabilitation of the top of the metropolitan tunnel shafts at an approximate cost of $5.5 million in the FY22-27 period.

- The rehabilitation of both the Lower and Upper Hultman is complete.

- Short term repairs to the Sudbury Aqueduct are also identified in the CIP (Phases 1 and 2) for an approximate total cost of $2.5 million to be done between July 2014 and July 2017. However, the need for this work will be reviewed as part of the ongoing redundancy concept planning. An additional $150,000 is included for inspection of the Weston Aqueduct.

- The Ash Street Sluice gates will be replaced in 2016 at an expected cost of $1 million.

- Electrical upgrades at Shaft 5 reflect the need to replace equipment approaching the end of its useful life. This project cost is approximately $1 million and the work would be done in 2019.

- Surface piping inspection and restoration at Shaft 5A/5 would begin in July 2014 with a one year duration and an approximate design and construction cost of $1.5 million. This work involves internal inspection of piping, restoration of coating systems and cathodic protection systems and thrust restraints and drainage system work.

- An inspection of the Quabbin Aqueduct is proposed to begin in July 2018 at an approximate cost of $2.8 million.

- Design is underway for a series of additional improvements to the Quabbin Aqueduct and to the Winsor Power Station. Work includes construction at Shafts 12 and 2 and rehabilitation of the Winsor Station. Replacement of the damaged Chapman butterfly valve at the Station with sleeve valves has already been completed. Design and construction of 5,000 linear feet of pipeline to convey 6 MGD of water from the CVA to the downstream trout hatchery has also been proposed and scheduled to begin in 2013. These combined improvements and repairs including design (excluding the

Quabbin Aqueduct inspection work noted above) are estimated to cost approximately $24.4 million.

- Replacement of the CVA Intake Motorized screens approaching the end of their useful life is schedule for FY18 at a cost of $500,000.

- Replacement of the Ware River Intake Valve is scheduled to begin in July 2015 at a cost of $1.2 million.

- Replacement of the outdated electrical control systems and switchyard at Oakdale is currently underway with a design and construction cost of approximately $3 million.

- Replacement of the Oakdale turbine is scheduled for 2020 at a cost of $1 million (see also Chapter 10 Energy Management).

- Building repairs to the Wachusett Lower Gatehouse to seal and thereby protect the building from further deterioration are scheduled to begin in July 2015 at an approximate cost of $2.2 million.

- Additionally, to further protect the building, a project to develop geothermal heat for the gatehouse is scheduled for May 2019 at a cost of $200,000.

- Rehabilitation of the Wachusett Gatehouse Chamber 4 piping is currently scheduled to be done in January 2019 at an estimated cost of $1 million.

Dam Projects already in the FY14 CIP**:**

- Ongoing dam safety modifications and repairs has a remaining value of approximately $421,000 for additional design work with proposed spending in the FY14-18 time period.

- The $1 million project for Goodnough Dike drainage improvements, scheduled to proceed in July 2014.

- Design for and the removal of the Oakdale dam at an estimated cost of approximately $950,000 primarily in FY14-18.

Projects recommended for future consideration:

Staff recommends consideration for the FY14-53 timeframe of the following projects with an estimated cost of approximately $92 million:

Redundancy projects:

- Program inspections of the Cosgrove Tunnel every 15 years at $0.5 million per inspection. Inspections will need to be seasonally scheduled to allow demand to be met by the Wachusett Aqueduct Pump Station (currently in design).The first of these recurring expenses would be scheduled for FY19. No repair or rehabilitation work is proposed at this time; however, this will be reevaluated following each inspection. Subsequent inspections within the time period of this Master Plan would be done in FY34 and FY49.

- A placeholder value of $65 million is proposed to address initial work to access, inspect and begin valve replacement as necessary in the Metropolitan Tunnel. This work is proposed for the FY30-45 time period which follows the completion of a redundant system that would allow the tunnels to be shut down. However, this placeholder value may be insufficient if any of the tunnel inspections were to find more significant damage.

Priority repair, rehabilitation and improvement projects:

- $8.6 million for Oakdale Phase 2 improvements which will incorporate remaining work at the Oakdale Power Station including building repairs and hydraulic control improvements.

- $7.5 million for dam-related projects, including ongoing long-term repairs to earthen and masonry dams ($6 million) and, Quabbin Lower Spillway Improvements ($1.5 million).

- $9.2 million to rehabilitate Nash Hill and Norumbega storage facilities.

7.2 Existing System Overview

As noted above, the system was built over time while maintaining the geographical advantage inherent to the Boston location. That is, while much of the service area is relatively low in elevation, supply sources are located at higher elevations allowing much of the system to be served by gravity. As the metropolitan areas in eastern Massachusetts grew, the service area expanded to include services areas served through the use of pump stations. However, approximately 80% of the water delivered by MWRA remains served by gravity flow. About one quarter of the MWRA communities pump some or all of the water delivered by MWRA to reach higher local service zones. Figure 7-1 shows the full system, including transmission and supply facilities currently held in reserve for emergency use. Table 7-1 provides overview information on each of the active and stand-by aqueducts and tunnels.

The principal structural components of the MWRA system consist of Quabbin and Wachusett Reservoirs, the Ware River intake and the deep rock tunnels and surface aqueducts that deliver water by gravity eastwards to the approximately 280 miles of pipe that distribute water to 44 metropolitan area communities. In addition, Clinton, Leominster and Worcester take directly from Wachusett Reservoir or the Quabbin Aqueduct and the Chicopee Valley Aqueduct (CVA) system delivers water to three communities to the southwest of Quabbin Reservoir, (i.e. Chicopee, Wilbraham and South Hadley Fire District No. 1).

Quabbin Reservoir has a maximum storage capacity of 412 billion gallons, equivalent to nearly six years worth of supply at current demands. It is fed by a well-protected watershed of 186 square miles. Quabbin Reservoir can also receive water from the Ware River watershed through the Shaft 8 intake structure, which diverts water to the Quabbin. Wachusett Reservoir has a maximum capacity of 65 billion gallons and is fed by a slightly more developed watershed that is 107 square miles.

Figure 7-2 shows system inflows and outflows. Runoff from the Wachusett Reservoir watershed is normally enough to support all metropolitan area demands in the spring but it needs supplemental supply from Quabbin in the drier months to maintain water elevation. The transfer of water from Quabbin is also essential to maintain high water quality in the Wachusett Reservoir. Ware River water is normally diverted to Quabbin in high runoff months to take advantage of Quabbin's long detention times to improve water quality. Flow out of the reservoirs is made up of withdrawals for water supply, required releases, and overflows when the reservoirs are full.

Water is discharged from the Quabbin Reservoir primarily from the Quabbin Tunnel, which has a flow capacity of 610 MGD. However, flow is restricted by the Oakdale Turbine and bypass valve capacity to approximately 300 MGD. The water enters the aqueduct at Quabbin Tunnel Intake, Shaft 12, and travels over 24 miles to Wachusett Reservoir. Releases from Quabbin also occur through the Chicopee Valley Aqueduct, which supplies an average of 8 MGD to three communities west of the Quabbin, and to the Swift River.

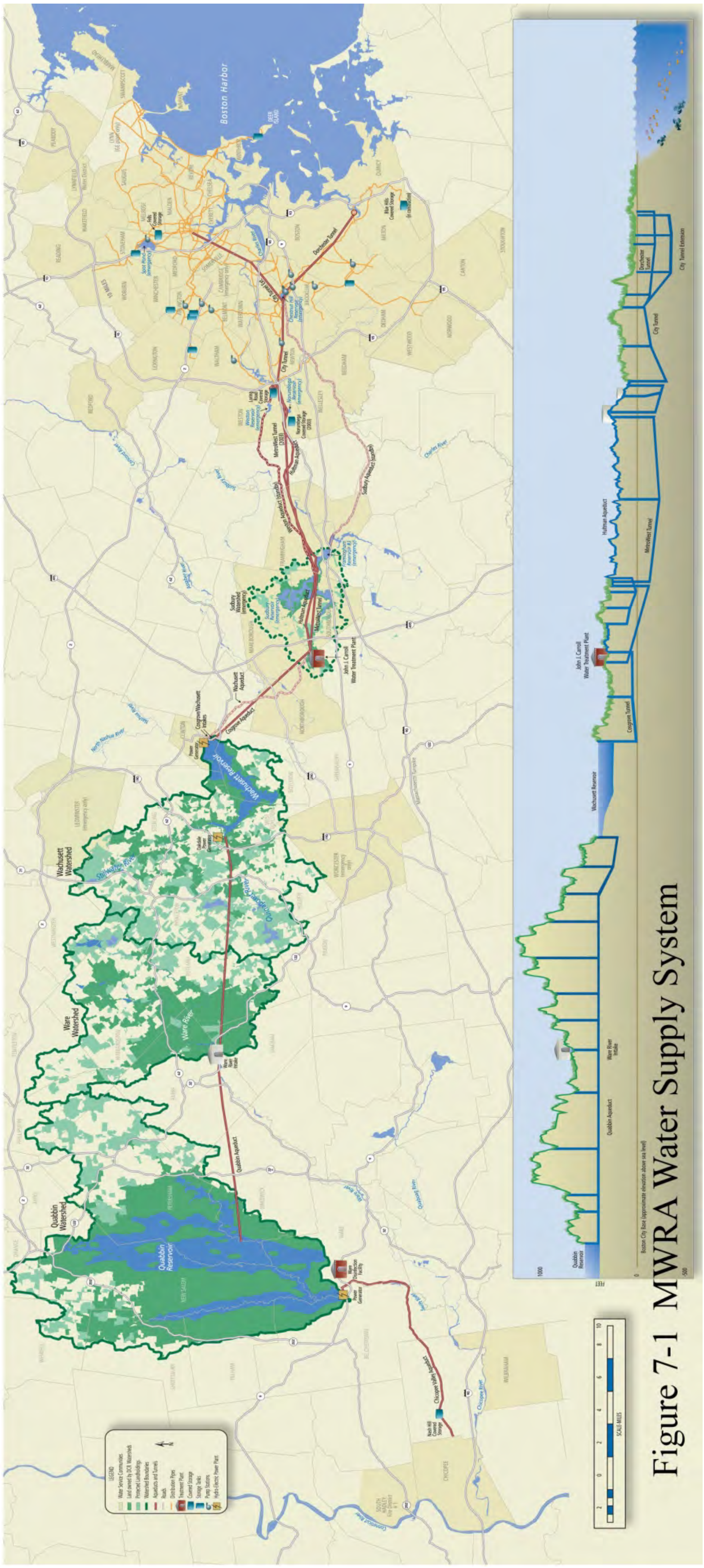


Figure 7-1 MWRA Water Supply System

Table 7-1
Overview Information on Aqueducts and Tunnels

Aqueduct/Tunnel	Year Built	Capacity (mgd)	Diameter (ft)	Length (miles)	Types of Construction	Status
Chicopee Valley Aqueduct	1949 [1]	24	3-4	14.8	steel reinforced concrete	Active
Quabbin Tunnel	1939	610	13	24.6	concrete lined rock	Active
Cosgrove Tunnel	1967	600	14	8	concrete lined rock	Active
Wachusett Aqueduct	1897 [2]	320	10-12	12	brick, concrete, open channel, gravity	Stand-by
MWWST	2003	450	14	17.6	concrete lined rock	Active
Southborough Tunnel [3]	1940	600	14	3	concrete lined rock	Active
Hultman Aqueduct	1940 [4]	325	11-12	15	concrete; steel	Active
Weston Aqueduct	1903	250	10-12	13.5	brick, concrete, gravity	Stand-by
City Tunnel	1950	300	12	5.4	concrete lined rock	Active
City Tunnel Extension	1963	200	10	7	concrete lined rock	Active
Dorchester Tunnel	1976	200	10	6.4	concrete lined rock	Active
Sudbury Aqueduct	1878	90	7-9	17.4	brick, gravity	Stand-by

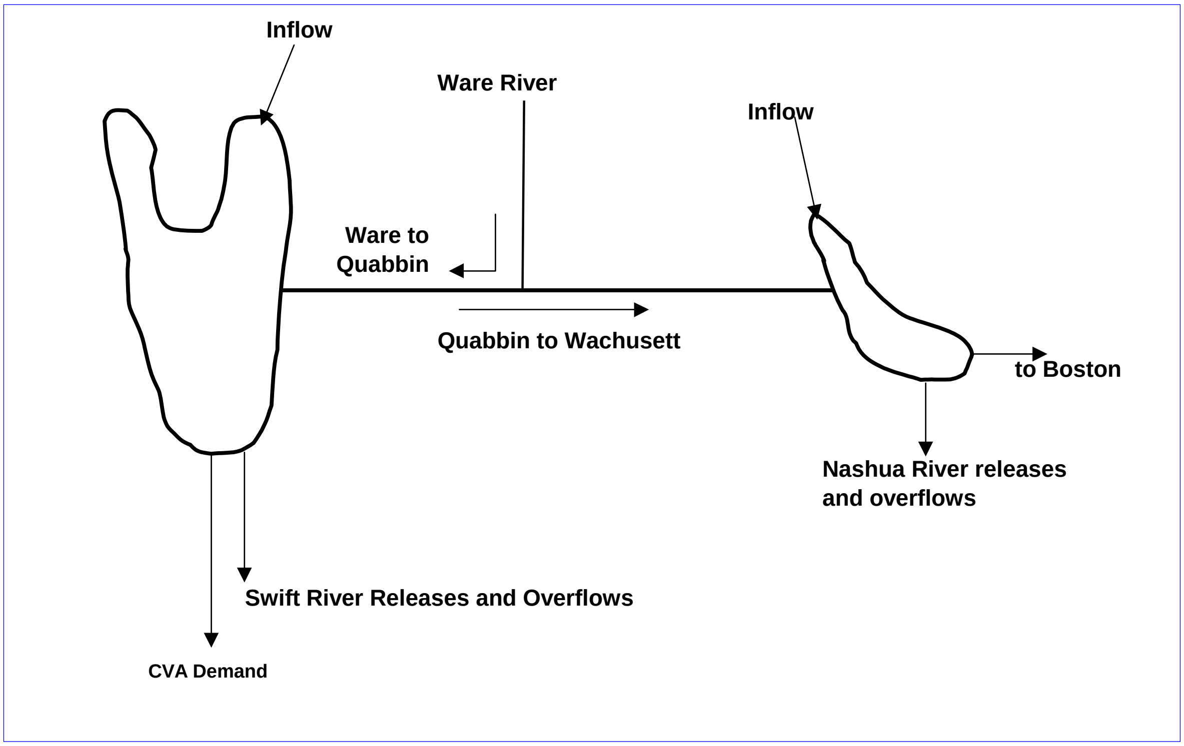
[1] Redundant sections completed in 2007

[2] Rehabilitation completed in 2002

[3] Part of Hultman system

[4] Rehabilitation completed in 2013

Figure 7-2 System Inflows and Outflows



When Ware River flow is diverted westward to Quabbin Reservoir, shuttered stop logs close at the Shaft 12 intake and force the water to discharge into the Quabbin Reservoir at Shaft 11A. This prevents the lower quality Ware River flow from accumulating around the Shaft 12 intake. Baffle dams direct the Ware diversion water northward into the reservoir and force the water to flow many miles to reach the Quabbin Tunnel intake structure at Shaft 12. As referenced in Chapter 4, Ware River transfers are limited to the portion of river flows above 85 mgd and are subject to the following conditions: no diversion of Ware River flows allowed from June 15 to October 15. Diversion from June 1 to June 15 and from October 15 to November 30 must have prior permission from the DEP Division of Water Supply.

Under normal operating conditions, the Cosgrove Intake and Tunnel carry 100 percent of the flow from the Wachusett Reservoir to the newly constructed John J. Carroll Water Treatment Plant ("CWTP"). This tunnel is backed up by the old Wachusett Dam Intake and the rehabilitated Wachusett Aqueduct, both of which were used in the winter of 2004/2005 while new connections to the CWTP were constructed. However, the Wachusett Aqueduct is limited in its flow capacity of 240-250 MGD which does not allow it to consistently meet summer demands. Also, since the aqueduct delivers water at a low elevation, it cannot supply flow into the ozone contactors at the CWTP and would require that temporary chlorination facilities be activated for treatment. It would also take at least a day to activate the Wachusett Aqueduct to deliver flow into the MetroWest Water Supply Tunnel (MWWST) for use in the metropolitan Boston area in the same manner that was done for the CWTP start-up. Since the CWTP plant flow system would not be supplied, the current supply to Northborough, Marlborough, Southborough and the Westborough

State Hospital would require special temporary pumping as was done temporarily during CWTP start-up but which was disassembled afterward. Please see the discussion of redundancy for the Cosgrove Tunnel beginning on page 7-12.

From the plant, flow can continue east from through the new MWWST or through the Hultman Aqueduct. The MWWST was constructed to remedy the significant lack of transmission system redundancy when the decision was made to not build the second barrel of the Hultman Aqueduct following WWII. Construction of the tunnel has eliminated a major weakness in the transmission system and has allowed MWRA to proceed with the necessary repairs to the Hultman Aqueduct. The MWWST tunnel also provided some hydraulic benefits and, given the depth of the tunnel (200-600 feet below the surface), provides additional security for the water transmission system. The role of additional stand-by facilities that can be used in the event of a catastrophic emergency is discussed on pages 7-29 through 7-37.

The Hultman Aqueduct is a 1940's vintage reinforced concrete pipeline for most of its length, the upper section being 12.5' diameter and the lower section being 11.5' diameter. A portion of the Hultman Aqueduct consists of the three-mile long tunnel section, known as the "Southborough Tunnel", which travels beneath the Sudbury Reservoir. The Hultman Aqueduct historically was connected to the Norumbega open storage reservoir, but is now connected to the CWTP and is being connected to the MWWST and to the new Norumbega Covered Storage Facility. When work on Hultman repairs is complete in 2013, either the MWWST or Hultman Aqueduct will be able to be isolated for emergencies with no loss of service to metropolitan Boston or the MetroWest communities.

East of the new Norumbega facility, the MWWST or Hultman Aqueduct flow can be directed to the 20 MG storage tank at Loring Road to supply the Boston Low service area. The facility can also be configured to supply the Northern Low Service area and the City Tunnel which feeds both the City Tunnel Extension to the north and the Dorchester Tunnel to the south. The City Tunnel, constructed in 1950, is a 12' diameter deep rock tunnel that extends five miles to Shafts 7 and 7B in Brighton. The City Tunnel Extension was constructed in 1963 and is a 10' diameter deep rock tunnel that goes from Shaft 7 north to Shaft 9A in Malden. The Dorchester Tunnel is a 10' diameter tunnel that extends southward from Shaft 7B to Shaft 7D in Dorchester. The Dorchester Tunnel was constructed in 1976. Shafts along each of these tunnel sections bring water up riser pipes that feed the distribution system.

7.3 Hydraulic Capacity Issues

As noted earlier, one of the prime functions of the transmission system is to ensure the capacity to supply maximum day demands for the foreseeable future. It should be noted that during the peak water use years in the 1980's, water demands had reached as high as 340 mgd with maximum days of well over 400 mgd. During these earlier periods, maximum day flow required the use of the older aqueducts, (e.g. Weston Aqueduct supply to Boston Low and Sudbury Aqueduct use with Chestnut Hill pumping). It also required the use of the large open distribution reservoirs like Spot Pond, Fells, Blue Hills, Chestnut Hill and Weston. These large reservoirs allowed the old Cosgrove/Hultman backbone to function, albeit with some bottlenecks and weaker max day hydraulic gradients to the distribution system. Addition of the MWWST has significantly improved hydraulic capacity but the replacement of older open distribution storage with smaller tanks has placed more of a peak hour burden on the tunnel backbone. The trend towards removal from service of local community tanks has also increased peak flows.

The net effect of these changes is that the current system with CWTP and the MWWST/Hultman backbone is adequate to meet projected maximum day demands but it should be noted that the goal of maintaining one day of distribution storage continues to be an important one to maintain transmission system adequacy.

7.4 Reliability and Condition Assessments-Normal Operations

The following section focuses on those parts of the Transmission system that are in active use under normal operating conditions for the system. Summary information is provided on redundancy shortfalls in the MWRA system and an overview of condition assessment information for the Transmission system is provided. Following that, each facility is discussed in greater detail and for each asset or facility notes what is known of the condition and what level of redundancy exists for that facility. Any current work in progress or identified for funding in the current CIP is identified and any future recommended projects are also discussed.

Reliability and Redundancy

To evaluate the ability of the Transmission system to meet the performance standard for reliability, one must consider both the risk of failure for any part of that system but also the consequence of a failure. To do this, information on the condition of the asset is critical to determining risk. The consequence of any particular failure can vary from insignificant to catastrophic. Redundancy in a water transmission system serves to reduce the consequence of failure because emergency back-up or stand-by facilities can be brought on-line. This means that the condition of these back-up facilities must also be ascertained and evaluated.

Redundancy Shortfalls

Table 7-2 provides an overview of the risk and consequence of failure for those tunnels and aqueducts (including surface pipe and other appurtenant facilities) that are used during normal operations. It must be noted that a number of the tunnels have not been able to be inspected since they cannot be removed from service. The Southborough Tunnel component of the Hultman Aqueduct was inspected as part of the early Hultman rehabilitation work and was determined to be in good condition. Since the previous Master Plan was completed in 2006, approximately $2.8 million has been added to the CIP for an inspection of the Quabbin Aqueduct. At this time there is still no means to inspect the City Tunnel, City Tunnel Extension or Dorchester Tunnel until redundancy plans have been designed and constructed and can be put into use.

Table 7-2 Risk and Consequence of Tunnel/Aqueduct Failure			
Aqueduct/Tunnel	**Age (yrs)**	**Risk of Failure**	**Consequence of Failure**
Quabbin Tunnel	73	Tunnel - Low Surface pipe - Moderate	Low
Chicopee Valley Aqueduct	63	Moderate	Moderate
Cosgrove Tunnel	45	Tunnel - Low Surface pipe - Moderate	High [1]
MetroWestTunnel	9	Tunnel - Low Surface pipe - Moderate	Low
Southborough Tunnel	72	Tunnel - Low Surface pipe - Moderate	Low
Hultman Aqueduct	72	Moderate	Low
City Tunnel	62	Tunnel - Low Surface pipe - Moderate	High
City Tunnel Extension	49	Tunnel - Low Surface pipe - Moderate	High
Dorchester Tunnel	36	Tunnel - Low Surface pipe - Moderate	High

[1] Pump Station which will allow the Wachusett Aqueduct to provide redundancy for the Cosgrove Tunnel is currently in design.

Completion of the MWWST has made the system significantly more robust and has alleviated much concern over a single-spine surface conduit as the major supply line to the metropolitan area. That said, there remain areas of concern where additional transmission improvements could increase operational flexibility both in the event of an emergency and would also allow regular inspection and rehabilitation of the system. Ideally, in the event of an emergency, the best resolution is to have a transition to a backup system that is unnoticeable by the end consumer. MWRA's system is not at that point and depending upon the location of a failure, service could be significantly disrupted.

In September 2008, the Board approved a contract with Fay, Spofford and Thorndike (FS&T) to study redundancy for the overall transmission system. The focus of the study was two-fold; to look at the Metropolitan tunnel system and to look at redundancy for the Cosgrove Tunnel.

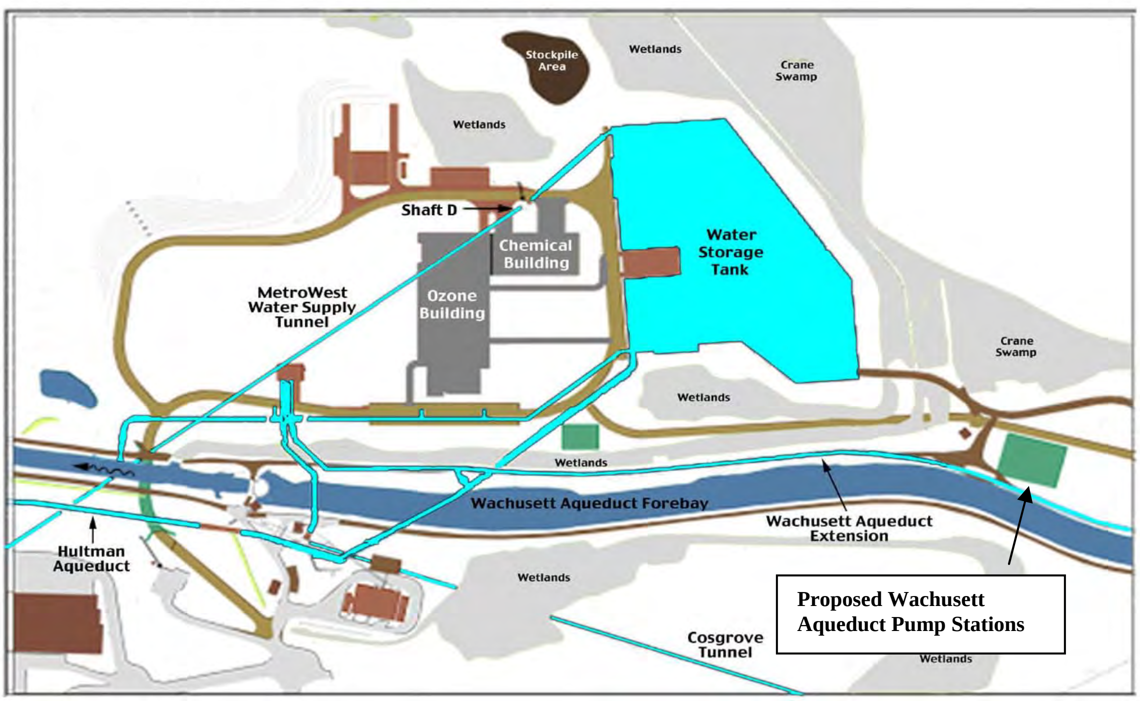
For the Cosgrove Tunnel, in 2003, an inspection of the tunnel noted the need for some repairs. Any repair project could require an extended shutdown of the Cosgrove Tunnel. The tunnel provides the primary raw water supply to the CWTP and is backed up by the stand-by, non-pressurized grade line, Wachusett Aqueduct. Although the Wachusett Aqueduct was rehabilitated in 2003 to allow its use during a short duration winter period in order to allow the Cosgrove

Tunnel to be connected to the CWTP, it is limited in both its flow capacity and by its inability to meet the grade line requirements of the CWTP. Flow from the Wachusett Aqueduct cannot supply water to the ozone contactors at the CWTP without pumping; use of the Aqueduct would require that the CWTP be turned off and temporary chlorination facilities be installed at the Wachusett Reservoir end of the Aqueduct to be used for treatment. This would also disrupt service to Northborough, Southborough, Marlborough, and to Westborough State Hospital.

The 2006 Master Plan recommended inclusion of $100 million as a placeholder for the provision of redundancy for the Cosgrove Tunnel. As part of the broader Concept Plan for Transmission system redundancy, the consultant considered two main alternatives: 1) Use the existing gravity Wachusett Aqueduct and construct a new emergency pump station at the CWTP site to boost the raw water in the Aqueduct to meet the required hydraulic grade line for the CWTP; and, 2) Pressurize the Wachusett Aqueduct through installation of a pipe within the existing structure with various pipe diameters considered.

Analyses showed that a pressurized Aqueduct could deliver more water to the plant, however, the additional cost of pressurization was over $100 million more than construction of a pump station. Although it cannot meet maximum day demands, a pump station could still deliver up to 240 MGD with the Cosgrove Tunnel out of service. In January, 2012, the Board of Directors approved the award of a design contract for the pump station.

Figure 7-3



The transmission system between CWTP and Shaft 5, the beginning of the City Tunnel, will be fully redundant after completion of the interconnections that are part of the Hultman Aqueduct repairs. This section will then be capable of seamless transfer of flow delivery, i.e. no significant service impacts, if either MWWST or Hultman requires an emergency shutdown.

The tunnels in the Metropolitan Boston area, (i.e. the City Tunnel, City Tunnel Extension and Dorchester Tunnel) remain a weak link. The need for Metropolitan system redundancy is driven by two compelling interests. First, MWRA must be able to respond quickly to a disruption in service. While the integrity of the underground tunnel sections is believed to be good based on very low unaccounted for water levels in the MWRA transmission system, there is still risk of failure, possibly due to major subsurface issues such as earthquakes but more likely due to pipe failures at the surface connections to the distribution system or at connecting valves (as seen in May 2010). Depending upon the location of such an event, this scenario could cause an immediate loss of pressure throughout the High Service area and may require isolation of the entire tunnel system (with extensive, difficult emergency valve closures), fabrication of specialized repair pieces and could take weeks or months to repair. Secondly, equally important to being able to address emergency scenarios, is the need to be able to take key parts of the tunnel system out of service periodically for inspection, maintenance and rehabilitation.

Although the assumption is that tunnels have a useful life of 100 years, due to the need to keep these lines in service, these subsurface structures have not been inspected and their actual condition is unknown. Facilities at the tops of tunnel shafts have been examined and a number of hardening measures are needed for risk reduction at these sites. Completion of planned distribution system storage projects like the Blue Hills Tanks also provide mitigation of the effects of a piping rupture at these points.

In the event of a failure of the City Tunnel, a limited amount of water could be transferred through the WASM 3 line (scheduled for major rehabilitation) and WASM 4 and the Sudbury Aqueduct would need to be brought on line. Extensive use of the Sudbury Aqueduct/Chestnut Hill Emergency Pump Station and open distribution storage at Spot Pond and Chestnut Hill would be required. Supply would be limited and a boil order would be put in place.

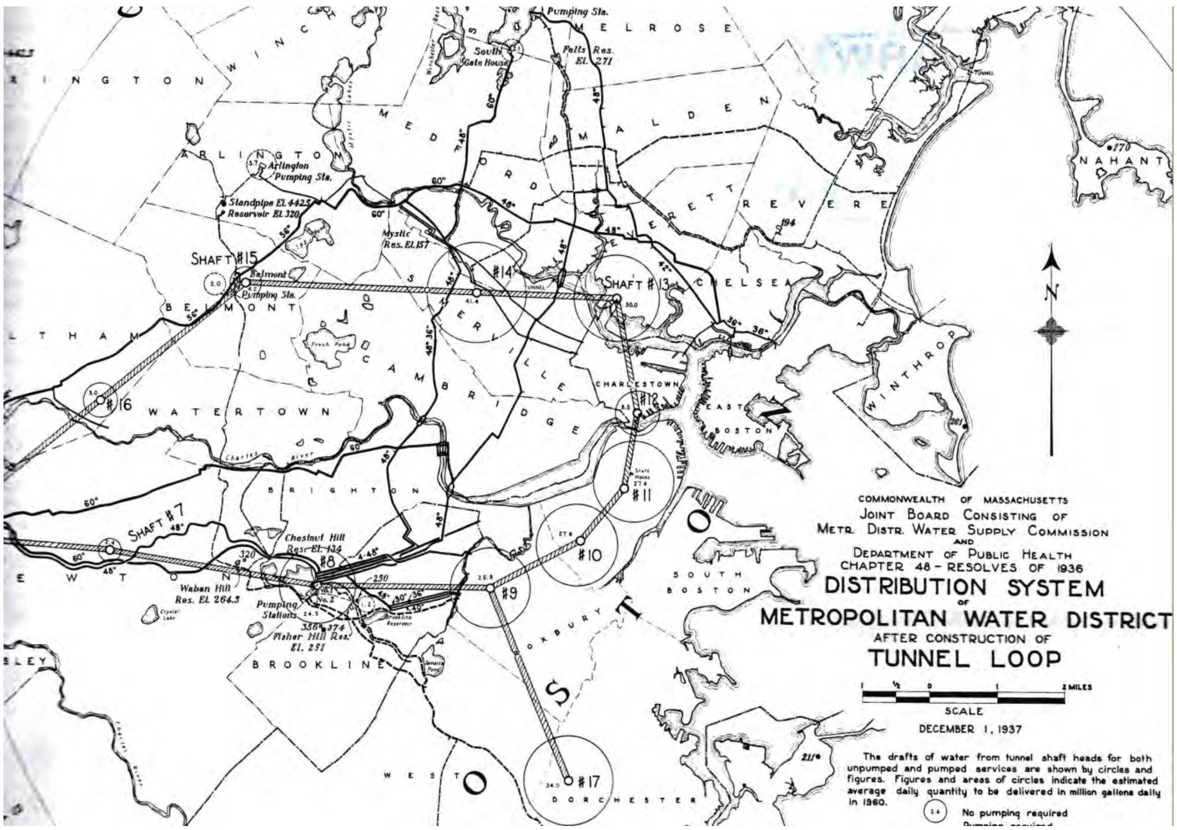
Failure of the City Tunnel Extension would be similar with reliance on WASM 3 and open storage at Spot Pond.

If the Dorchester Tunnel were to experience a problem, flow could be routed to the south through surface mains. However, this relies on the construction of additional surface pipelines at the Chestnut Hill Reservoir area.

MWRA's predecessor agencies began considering redundancy for the tunnel system as early as the 1930's when a preliminary plan to construct a Northern Tunnel Loop (See Figure 7-4) was identified. The 2006 Master Plan recommended that a CIP [placeholder value of $100 million be included to support redundancy planning for the Metropolitan system. The goal of the planning work begun in 2008 was to re-examine redundancy options. Consideration of a full tunnel loop was part of that review, but given the significant decreases in system demands, the Consultant was also asked to review the existing system and current and proposed CIP projects to see whether there were ways to use existing or modify proposed facilities to develop redundancy alternatives that would optimize use of the existing system.

The initial study tasks looked at existing hydraulic capacity within the MWRA system and identified the impacts of various failure scenarios of the Metropolitan tunnel system on both the level of service that could be provided and the hydraulic grade line at each of the community meters. Alternative improvements to mitigate the impacts associated with key tunnel segments were then developed and evaluated. The most significant points of failure within the system are those that might occur at Shaft 5 and at Shaft 7.

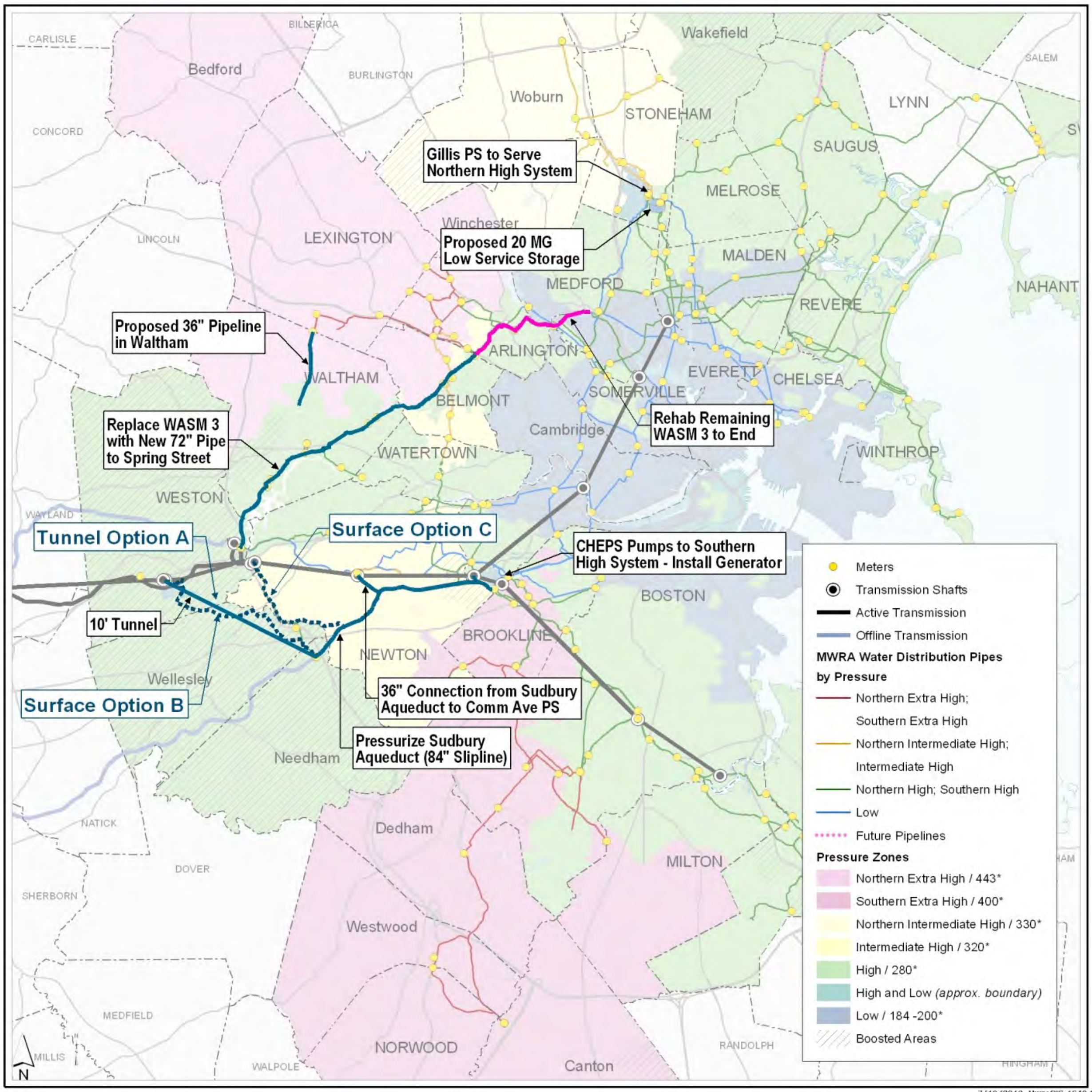
Figure 7-4



Fifteen alternatives were evaluated; four alternatives, including a tunnel loop alternative, were developed for various demand scenarios and 11 alternatives were developed to meet average demands. Alternatives that meet average demands allow maintenance to be scheduled and completed during three seasons but cannot meet normal summertime demands if work were to extend beyond the spring or in the event of an emergency during high-demand periods. Under such scenarios, demand reductions through mandatory restrictions and possible supply limitations to some partial user communities, may be necessary.

The 15 alternatives were evaluated for a range of criteria and further narrowed. Although the tunnel alternative provides full redundancy for maximum day demands, it was prohibitively expensive (in excess of $1 billion) and over-designed for normal operations. Alternatives using existing, modified or new surface pipelines with possible tunnel segments appeared to be more cost effective and to meet the project goals. Figure 7-5 below shows the preferred alternatives for Metropolitan redundancy following this initial study.

Figure 7-5



As shown on the figure, the northern portion of the work entails replacement of the 60-inch diameter sections of WASM 3 with 72-inch diameter pipe north to Spring Street; rehabilitation of the remainder of WASM 3 and, construction of a 36-inch pipeline to Waltham (See Chapter 8). On the southern portion of the project, additional alternatives included either surface pipelines or tunnel options and the pressurization of the Sudbury Aqueduct from a more western location to Chestnut Hill. Further connections would then need to be made from Chestnut Hill to the Southern High system. An additional unresolved question concerns the starting point for the proposed southern component. Alternatives considered included connection points at Norumbega Reservoir or at the Shaft 5 area. The Shaft 5 area allows for a shorter distance but is a more congested site from a construction standpoint and raises concerns about protection of existing structures during construction.

Following the completion of the Concept Plan, MWRA has initiated an RFQ/P for a follow-up plan to better define the proposed southern component through additional rigorous alternatives analyses and to undertake MEPA review of the recommended alternative. The RFP lays out the proposals to be examined as follows:

The current schedule for this project, (Southern Component, Sudbury Aqueduct Pressurization and Connections), beginning at the Notice to Proceed date; includes 2 years for this Alternatives Analyses and MEPA Review, followed by a 2 ½ year Preliminary and Final Design, followed by construction beginning in 2020. Construction is scheduled to be completed in 2024.

An Environmental Notification Form (ENF) will need to be filed by MWRA with MEPA since the redundancy project is greater than five miles in length. The evaluation of alternatives will focus primarily on the connection (surface pipeline vs. tunnel) from MWWST/Hultman Aqueduct to the Sudbury Aqueduct (Segment 1) and will also include Segments 2 and 3 as described above. For Segment 1, the Conceptual Design report (CDR) currently recommends either a 10 foot finished diameter deep rock tunnel of 3.7 miles length or choosing from three alternative surface pipeline routes installing a 72 inch to 120 inch diameter pipeline for lengths between 2.8 and 5.8 miles. This project will advance the previous analysis of alternatives with more extensive hydraulic analyses, environmental assessments, geologic evaluation, and screening and ranking of alternatives. The project culminates in a recommended plan, including results of the alternatives analysis, for MEPA submission and Secretary's Certificate on the ENF. This project will also examine contract packaging, and alternative project delivery methods, including the applicability of design build contracting, in the context of their potential to optimize overall project cost and implementation schedule.

It is anticipated that after receipt of the Secretary's Certificate, MWRA will procure a separate design contract to advance the project through preliminary and final design under the contract delivery method that best serves to expedite a construction NTP at the earliest date possible.

Recommended Redundancy Projects:

To address these shortfalls in system redundancy, the FY14 CIP has replaced the placeholder value with the following projects related to Transmission system redundancy:

- Approximately $318 million allocated to the southern part of the long-term redundancy solution for the Metropolitan tunnels and approximately $50 million allocated for Cosgrove Tunnel redundancy through construction of a pump station.

Pump Station design work has begun and additional concept refinement and MEPA review for the southern section is anticipated to begin in 2012.

- A project has also been added to the CIP to address rehabilitation of the top of the metropolitan tunnel shafts at an approximate cost of $5.5 million in the FY22-27 period.

- Short term repairs to the Sudbury Aqueduct are also identified in the CIP (Phases 1 and 2) for an approximate total cost of $2.5 million to be done between July 2014 and July 2017. However, the need for short-term repairs will be further investigated as part of the engineering analyses and scheduling of redundancy projects. An additional $150,000 is included for inspection of the Weston Aqueduct.

- An inspection of the Quabbin Aqueduct is proposed to begin in July 2018 at an approximate cost of $2.8 million.

The northern component of Metropolitan redundancy primarily involves rehabilitation and replacement of the existing WASM 3 pipeline (in part with larger diameter pipe) and this is discussed in Chapter 8.

<u>Condition Assessment</u>

In 2006, a consultant study, called the *Transmission Facilities Engineering Assessment* was completed. This project included inspections of key transmission facilities and top of shaft structures. Reports on condition assessment, recommendations and costs were developed. The recommendations were tiered and considered both the minimum level of work necessary to operate or stabilize the asset and also potential additional measures that might enhance the operation of the facility or bring the facility fully up to its original condition. Given the historic status and architectural style of many of the facilities, the latter level of rehabilitation may not be financially feasible at this time. Thus, improvements to halt any ongoing deterioration and ensure safe and secure facility operation may be the short-term course of action with the study serving as the blueprint for the requirements to fully bring the asset up to its original condition, if desired, over a longer time frame. Many of the projects identified in the FY14 CIP derive from this planning effort.

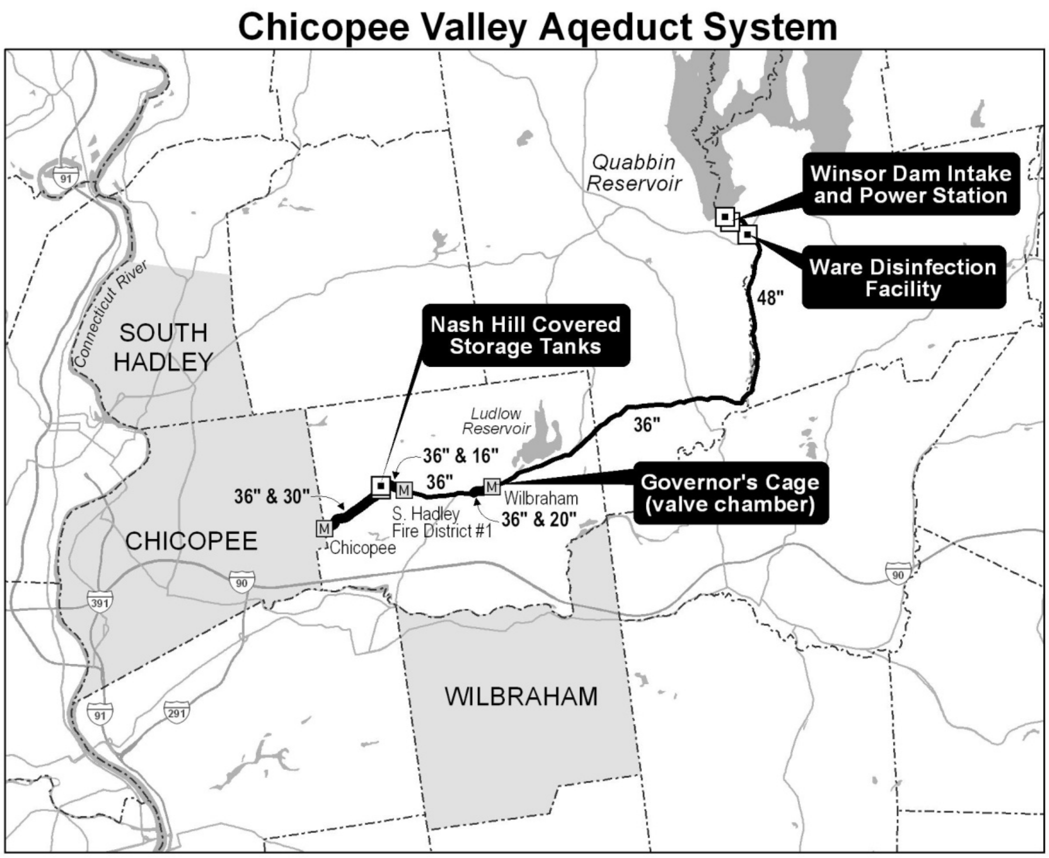
The following section focuses on those parts of the Transmission system that are in active use under normal operating conditions for the system. Each facility is discussed in greater detail and for each asset or facility notes what is known of the condition and what level of redundancy exists for that facility. Any current work in progress or identified for funding in the current CIP is identified and any future recommended projects are also noted.

Chicopee Valley System *(shown in Figure 7-6 below)*

Chicopee Valley Aqueduct

The Chicopee Valley Aqueduct was initially constructed in 1949 to serve the communities of Chicopee, Wilbraham and South Hadley Fire District #1. The Aqueduct extends approximately 15 miles in length and is reinforced concrete pipe with an embedded steel cylinder. The pipe varies from 36”-48” in diameter. The pipe has a capacity of 23 MGD which is sufficient to meet peak summer demands.

Figure 7-6



In 2007, MWRA completed construction of a 30-inch diameter 8,100 foot long second barrel of the CVA from Nash Hill Covered Storage to the City of Chicopee; 3,100 feet of 16-inch redundant pipeline between Nash Hill Covered Storage and the take-off point for South Hadley; and 2,400 feet of 20-inch redundant pipeline between the Route 21 valve chamber and the Wilbraham takeoff. With these new pipelines in place, the communities will be connected to Quabbin Reservoir, Nash Hill Covered Storage or both in the event of a failure along the Aqueduct.

Associated CVA Structures and Facilities

CVA Intake Facility

The CVA Intake structure controls water flow from the Quabbin Reservoir into the Chicopee Valley Aqueduct. It also conveys water to be released to the Swift River. It is located on the Winsor Dam and is partially located in the Reservoir itself. It houses two bays with rotating screens to prevent debris from entering the aqueduct. The rotating screens and spray water pump system are nearing the end of their useful life and will need replacement. In addition, the isolation valves are old and will need replacement sometime in the future.

Winsor Power Station

The Winsor Power Station was constructed below the Winsor Dam to house the valving and hydrogeneration equipment associated with supplying the CVA and releasing water to the Swift River. The facility had actively generated power on the flow being released to the Swift River until an electrical system fire in 1991. In addition to damage from the fire, the overall facility is now over 65 years old and the pipes and valving need replacement based on recent condition assessments and leakage problems. A new head dissipating valve was installed to allow for safer releases to the Swift River as part of a first phase of rehabilitation of the facility. Restoration of hydrogenation capability at this station raises significant technical and permitting issues, including issues relative to release requirements, which MWRA has elected to not address at this time.

Ongoing Work:

- The FY14 CIP includes the ongoing work to upgrade the Winsor Power Station including upgrading of the large diameter piping and associated valving as well as rehabilitation of the building and electrical system. This CIP project also includes replacement of the antiquated shutter system that was the sole means of controlling flow in the Quabbin Aqueduct with a new roller gate (See *Quabbin Intake Structure at Shaft 12* below). The project also includes design and construction of 5,000 feet of pipeline to convey 6 MGD of water from the CVA to the downstream trout hatchery. This will provide a consistent and reliable source of high quality cold water to the hatchery as well as supplementing Swift River flows. A small hydro turbine is included in this project and this is further discussed in chapter 10.

Ware Disinfection Facility

The Ware Disinfection Facility has two main purposes, the first being to provide primary disinfection using sodium hypochlorite, and the second being flow regulation via SCADA controlled throttling valves to supply CVA demands in response to Nash Hill Tank variations. The facility was constructed in 1999. In order to comply with the future Cryptosporidium Rule that requires two means of disinfection, addition of UV disinfection is planned at this site (see Chapter 6).

Ludlow Monitoring Station

Ludlow Monitoring Station is located approximately 12 hours (on average) of flow travel time downstream of the Ware Disinfection Facility and above the first CVA user (the Wilbraham meter). The facility consists of a small building that encloses sampling and SCADA equipment. The facility monitors chlorine residual for determination of disinfection effectiveness..

Nash Hill Tanks

The Nash Hill Tanks are two 12.5 MG above ground pre-stressed concrete storage tanks which were constructed in 1998 to replace an existing open water surface reservoir. The open reservoir was disconnected and serves only as a detention basin for any overflows.

Recommended Project:

- $1.1 million is recommended in FY19-21 for rehabilitation of the Nash Hill tanks.

Nash Hill Service Building

The Nash Hill Service Building is a one story garage type building that is near the entrance of the Nash Hill Tank site. Its purpose is for storage of maintenance equipment associated with buildings and grounds maintenance of the CVA.

Quabbin Reservoir to Wachusett Reservoir

Quabbin Tunnel

The Quabbin Tunnel was constructed in the early 1930's and was initially brought on line for the diversion of Ware River water to the Wachusett Reservoir during that time prior to the completion of Quabbin Reservoir. In addition to access, many of the shaft locations have specific functions as outlined below. At these locations, there are some above-ground facilities. Although there is no redundancy to the Quabbin Tunnel, water could be provided from Wachusett Reservoir for a duration of six months or more during which repairs could be made to the tunnel.

Planned Work:

- The FY14 CIP includes approximately $2.8 million for an inspection of the Quabbin Tunnel.

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Quabbin Tunnel Structures and Facilities

Quabbin Intake Structure at Shaft 12

This is the location where flow enters the tunnel for transport to the Wachusett Reservoir. Reservoir water enters the building's intakes, passes through shuttered stop logs and screens and enters the tunnel which is 125' deep at this point. It is a 40' x 30' granite block structure with a concrete substructure and pitched slate roof. Power for this building and the Shaft 12 service building is provided by a manually operated propane generator. A permanent power supply is needed for desired security system upgrades.

Projects in the FY14 CIP:

- If the water piping in the Oakdale Power Station were to fail, there is currently no way to stop the flow of water. The Shaft 12 structure has stop log bays but it is an intensive process to remove the stop logs to set the shutter valves in the opposite direction and this cannot be done on an emergency basis while flow is moving. The FY14 CIP contains approximately $8.6 million to for design and installation of a roller gate at Shaft 12 to improve safety and reliability of the transmission system. Building rehabilitation work at Shaft 2 is also being done as part of this contract.

Shaft 12 Service Building

This building is located about 240' away from the intake building and is of similar size and construction. The building houses two garage bays, a bathroom and two additional rooms. No major facility work is required.

Shaft 11A Ware River Diversion Discharge

This shaft is used to discharge flow into the Quabbin Reservoir through shuttered stop logs when the Ware River is being diverted towards Quabbin via the Quabbin Tunnel. During normal operation, this shaft acts as a vent and access point for the aqueduct.

Misc. Shaft Structures with no Buildings

At a number of the shaft locations without larger, ancillary facilities, relatively minor improvements in physical hardening are recommended.

Quabbin Aqueduct Shaft 9

The headhouse at this location provides access and pressure relief for the Quabbin Tunnel. Pressure relief is particular important when Shaft 8 is being used for diversion of water from the Ware River. It is a granite block structure approximately 29' x 21' with a concrete substructure and a pitched slate roof. Minor building improvements appear to be required to maintain the integrity of the structure.

Shaft 4

This tunnel shaft serves as an access point and air relief structure for the Tunnel. There is no electrical service or heat in the structure which is approximately 30' x 19' in size. It is a granite block structure with a pitched slate roof. Minor building improvements appear to be required to maintain the integrity of the structure.

Shaft 3

This is the location where the City of Worcester Interconnection Building is located. This allows the City to take water from the Quabbin Aqueduct on an emergency basis with prior notification to MWRA. This facility is the responsibility of Worcester and is in poor condition.

Shaft 2

This shaft provides pressure relief for the Quabbin Aqueduct by allowing overflows and venting air both in and out of the tunnel. Typical operations avoid overflows at this location but they can occur during high volume transfers from the Ware River to either Quabbin or Wachusett Reservoirs. It is an above ground concrete structure and is in poor structural condition. Upgrades to this structure are included in the same contract as the installation of gates at Shaft 12.

Oakdale Power Station

The Oakdale Power Station is at Shaft 1 of the Quabbin Tunnel and is the terminus of the tunnel where it flows through a 3.4 MW turbine and combines with the Quinapoxet River to flow into the Wachusett Reservoir. Within the structure, water flows up Shaft 1 and is split between a generator penstock inlet pipe and a bypass pipeline. A brand new 84-inch butterfly valve provides isolation for the generator. Flow through the bypass is controlled by a new 72-inch butterfly valve and fixed orifice sleeve valve. The structure dates from the construction of the Quabbin Aqueduct and the generator was added around 1950 with limited electrical upgrades done around 1991. Piping and valve rehabilitation was completed in 2006.

Projects in FY14 CIP:

- Work is ongoing to design and construct improvements to the 60 year old electrical control systems and switchyard at the Oakdale facility. These facilities both run the turbine and connect the facility to the grid. These facilities are both technologically obsolete but can also present a safety hazard given the specialized antique equipment and localized knowledge necessary to operate the facilities. The cost is approximately $3 million.

- A future project to rehabilitate the Oakdale turbine has been added to the CIP for May 2020 time period at an estimated cost of $1 million. The turbine was installed in 1986 and although it is currently operating, it has an expected useful life of 30 years.

Recommended Project:

- Phase 2 of the Oakdale project was deleted from a previous CIP and this included $8.625 million to improve hydraulic controls and provide additional transfer capacity to Wachusett Reservoir. This work is still necessary and building repairs to stem deterioration are also required.

Ware River Facilities

Lonergan Intake and Service Building

Shaft 8 (elevation 656') on the Quabbin Tunnel, also known as the Lonergan Intake, is the location where water is withdrawn from the Ware River (seasonally and flow restricted as noted in Chapter 4) and dropped into the Quabbin Tunnel. This facility was constructed in 1931 and was used at that time to supplement the volume of water available from Wachusett prior to the completion of construction at Quabbin. Although flow in the tunnel can be directed in either direction, for water quality reasons, Ware River flows are normally directed to Quabbin (elevation 530') rather than to Wachusett Reservoir (elevation 395). A dam across the Ware River extends from the intake building and the bypass flow to the downstream reach of the river is controlled by the intake building. Flow into Shaft 8 passes through a system of siphons which is primed by the bypass water flow. The facility has an automated control system using floats, pneumatics for siphon priming and hydraulically controlled valves to control the diversion rate but the equipment is old and not normally operated in automatic mode. The building is a granite block superstructure, with a pitched slate roof set on a concrete plant structural steel support system and a reinforced concrete substructure. The building size is approximately 78' x 65' x 29' high at the eave. Although this ingeniously designed system works, in the long term, it is desirable to simplify facility start-up and SCADA controls are planned to allow unstaffed operation and remote monitoring of the facility and replacement of the siphon system. Valves are currently hydraulically actuated using an oil system which should be corrected thus valve and/or actuator replacements may be necessary.

There is no redundancy to these facilities, however, given the seasonal restrictions on taking Ware River water, it is expected that any necessary repairs could be made without impacting the ability to provide water from Quabbin or Wachusett Reservoirs.

The Shaft 8 Service Building is a single story structure containing three garage bays, a maintenance room, an office and bathrooms. The building is approximately 59' x 37' and is a granite block structure with a pitched slate roof atop a concrete slab. No major improvements appear to be necessary.

<u>Projects in FY14 CIP:</u>

- A project that addresses the above issues by replacing the underwater, inaccessible, oil-actuated valves with electric actuated valves. In addition, the siphons will be replaced with hard piped intakes and equipment will be automated with remote control capabilities. This project is scheduled to start July 2015 at an estimated cost of $1.2 million.

<u>Barre Lower Garage</u>

The Barre Lower Garage is a former textile mill building. It is a large single story structure with brick exterior walls wooden flooring, interior walls and roof system. It was built prior to the 1930's water supply development of the site. The first floor is supported by a stone and concrete foundation walls and wooden beams and columns resting on concrete piers in the basement. Besides storage, the first floor houses an office, bathroom and lunchroom. A mechanical room in the basement houses the furnace, well water tank and hot water heater. The building is approximately 50' x 133' in size. Minor building improvements appear to be required to maintain the integrity of the structure.

<u>Wachusett Reservoir Facilities</u>

<u>Cosgrove Intake</u>

The Cosgrove intake building was constructed in 1967 and is the sole active intake from the Wachusett Reservoir. Water passing through the facility enters the Cosgrove Tunnel at Shaft A located near the intake building. Water flows through the intake screens into intermediate wells. It is then controlled through bypass sleeve valves or through one of two 1.7 MW hydroelectric turbines. The water passes into a stilling basin and then through a horizontal tunnel to Shaft A of the Cosgrove Tunnel. The building is approximately 116' wide x 147' long but the substructure depth ranges from 70-100' below the first floor.

In the mid-1990's this building experienced cracking of wall tiles which may have been associated with some slight movement of the building. Minor water damage due to leakage has also been noted in the structure. In-house and outside experts evaluated these areas and monitoring of these areas was initiated on a regular basis. There does not appear to have been any subsequent movement and the building has been deemed to be fundamentally structurally sound during the inspections.

<u>Algae Control Chemical Feed System</u>

Management of algae at Wachusett Reservoir has always been done manually using application of copper sulfate distributed by boat. This has been very effective for algae species that bloom on the reservoir surface but is less effective when the algae is dispersed in the water column. There have also been infrequent nuisance algae below the surface during winter months when there is an ice cover that doesn't allow copper sulfate dosing. Following studies and piloting, the Master Plan recommended implementation of an algae dosing system which would consist of piping placed in the reservoir to supply copper sulfate solution to an anchored underwater mixer to dose the area of concern in front of the intake. This project is in the FY14 CIP at an estimated design and construction cost of $2.25 million and is scheduled for design in July 2015 (see table 6-3). However, since 2006, significant algae concerns have been infrequent and are addressed to the extent feasible through reservoir operations. In addition, ozone treatment appears to address taste and odor issues associated with some species of algae. For these reasons, it is recommended that this project be left in the CIP but that implementation not move forward at this time.

Wachusett Reservoir to Shaft 5

Cosgrove Tunnel

The Cosgrove Tunnel was completed in 1967 and is a concrete lined, deep rock tunnel approximately 8 miles in length that extends from the Power Station and Intake to Shaft C in Marlborough. This 14' diameter tunnel is designed to operate under pressure and has a potential capacity of 615 MGD. However, with hydraulic restrictions at Shaft B and the elevation of the CWTP inlet, this capacity cannot be met. At its deepest point, it is over 500 feet below grade. There are three shafts along the alignment with Shaft A at the intake, Shaft B at the midpoint (a hydraulic relief structure to prevent over-pressurization which was raised and rehabilitated in 2003) and Shaft C which is the outlet at the Carroll Treatment Plant site. The tunnel was taken off-line during the winter of 2003 in order to make connections between the tunnel and the new treatment plant. This allowed the tunnel to be inspected using submersible technology in December of 2003.

A Remotely Operated Vehicle (ROV) performed the tunnel inspection using sonar technology to capture detailed information using Shaft B as the point of access in order to be able to go both directions from that location. Results of the inspection indicated circumferential, longitudinal and multiple cracks (a combination of circumferential and longitudinal cracks) were observed throughout the tunnel length. The consultant report prepared in 2004 concluded that the tunnel was not in imminent danger of collapse, but recommended that structural repairs to the tunnel liner be completed and that a more detailed risk assessment be conducted to focus on tunnel liner stability and to identify potential failure scenarios and the probability of the tunnel lining failing under those scenarios. A subsequent review of the available information in 2012 resulted in the recommendation that the tunnel continue to be inspected at 15 year intervals with the initial inspection in the FY19 time period.

As noted previously, there is not full redundancy for the Cosgrove Tunnel at this time. The gravity flow Wachusett Aqueduct can provided up to approximately 240 MGD The delivery gradient at the terminus of the Wachusett Aqueduct is only approximately 280' which is inadequate to supply water through the CWTP ozone contactors and to directly supply some of the MetroWest communities. Therefore, use of the Wachusett Aqueduct as it exists today would require temporary chlorine disinfection in place of ozonation and temporary pumping to some MetroWest communities as was done during the Cosgrove Tunnel shutdown preceding CWTP start-up. The 2006 Master Plan recommended that either pressurization of the Wachusett Aqueduct or construction of a pump station be further studied in order to allow the Cosgrove

Tunnel to be taken off-line for further inspection or repairs. The proposed Wachusett Aqueduct Pump Station is discussed on page 7-13.

Recommended Projects:

- Program inspections of the Cosgrove Tunnel every 15 years at $0.5 million per inspection. Inspections will need to be seasonally scheduled to allow demand to be met by the Wachusett Aqueduct Pump Station (currently in design).The first of these recurring expenses would be scheduled for FY19. No repair or rehabilitation work is proposed at this time; however, this will be reevaluated following each inspection. Subsequent inspections within the time period of this Master Plan would be done in FY34 and FY49.

MetroWest Water Supply Tunnel

The MetroWest Water Supply Tunnel came on line in November, 2003 as the major transmission facility from the CWTP to the Norumbega Covered Storage Facility and on to the City Tunnel connection at Shaft 5. The tunnel is a 17.6 mile long, 14-foot diameter deep rock tunnel (with a 14-foot diameter connection to the Loring Road Covered Storage Facility) and it was constructed to ensure that there was a redundant means of providing water to the metropolitan area in the event of a failure along the Hultman Aqueduct. Ultimately, the tunnel will work in parallel with the Hultman Aqueduct and the interconnections will allow both improved ability to respond to service disruptions or concerns on either the tunnel or the Hultman and will allow for either facility to be taken out of service for inspection and maintenance. Currently, sections of the Hultman Aqueduct are off-line until they can be fully inspected, rehabilitated and new interconnections made with the tunnel and the Norumbega Covered Storage Facility. MetroWest communities previously connected either to the Wachusett Aqueduct (Town of Northborough, Westborough State Hospital) or only to the Hultman Aqueduct (City of Marlborough, Towns of Southborough, Framingham, Weston, Wellesley and Needham) now have either direct connections to the MWWST or indirect connections via new interconnections between the Hultman Aqueduct and the MWWST.

Hultman Aqueduct

The Hultman Aqueduct, a surface aqueduct, was constructed in 1940 and is a pressurized concrete pipeline 18 miles in length extending from the CWTP in Marlborough to Shaft 5 in Weston. Flow could also be diverted to the Norumbega Open Reservoir (now off-line). The Hultman initially was designed to take water from the Wachusett Aqueduct's open channel. The system was modified in the 1960's when the Cosgrove Tunnel was constructed and was modified again in 2005 with connection to the CWTP. The Hultman was also designed to be able to deliver water to the Low system through the Weston Aqueduct (now on emergency stand-by status) and by using the 7' Branch to supply Loring Road Tanks[1]. The initial Hultman plans called for the

[1] The Hultman Aqueduct 7-foot branch provides a connection from the Hultman Aqueduct immediately upstream of Shaft 5 to the Weston Aqueduct Supply Main at River Road in Weston and ultimately to the Loring Road Storage Facility.

construction of a second barrel of the Aqueduct in the same right-of-way for redundancy and operational flexibility. This second barrel was delayed and, ultimately, the MWWST was built to provide that redundancy. The Hultman ranges between 11.5 and 12.5 in diameter but the Southborough Tunnel which is the 3 mile section of the Hultman that transverses under Sudbury Reservoir is a 14 foot diameter deep rock tunnel. The major work to rehabilitate the Hultman was completed in 2012; remaining work on the Upper Hultman was completed in 2013.

Southborough Tunnel

The Southborough Tunnel section of the Hultman Aqueduct was inspected in as part of the early Hultman Aqueduct rehabilitation work and was found to be in good condition. No deficiencies were noted. This tunnel should be re-inspected in 25 years.

Southborough Facilities

Most administrative and maintenance activities for Western Operations are centered at the MWRA's Southborough facilities at the Sudbury Dam site. The administrative offices and maintenance shops were constructed in 1996. The water quality lab (see Chapter 8) is expected to get a new roof under the contract to modify existing facilities. Some of the trade shops from Southborough will be relocated to the former Interim Corrosion Control Facility (ICCF) which is no longer in use. The design for the rehabilitation of the ICCF is being finalized and construction is expected to proceed in FY14.

Shaft 5 to the East

City Tunnel

The City Tunnel, constructed in 1950, is a 12' diameter deep rock tunnel that extends five miles to Shafts 7 and 7B in Brighton. Shaft 5 is the location where flow enters the City Tunnel from either the MWWST and/or the Hultman Aqueduct. Shaft 5 has experienced significant building and electrical/mechanical deterioration as a result of condensation within the building when the tunnel is venting. In addition, due to the alternating wet and dry conditions at this location, it may be necessary to overhaul electrical equipment and to replace motors in order to ensure that valves can be operated. Some physical hardening and improvements to facility access are recommended at the remaining City Tunnel shaft locations.

City Tunnel Extension

The City Tunnel Extension was constructed in 1963 and is a 10' diameter deep rock tunnel that goes from Shaft 7 north to Shaft 9A in Malden. Shafts 8, 9 and 9A each have pressure regulated connections to the Northern Low. Shafts 9 and 9A supply water to the Northern High. As with the City Tunnel, the shaft structures along the City Tunnel Extension are in need of more physical hardening and improved facility access for maintenance. The Shaft 9 building, in particular, is in poor condition both internally and externally, and site security improvements should be made to prevent further vandalism at the site.

The building at Shaft 9A was previously used to boost chlorine residual through the addition of gaseous chlorine. Due to system improvements, this is no longer necessary and equipment has been removed. This building, located in Malden, is still used for crews to take regular water quality samples. Needed improvements at this site are expected to be minimal and will primarily consist of security upgrades. Shaft 8 structures are below ground and improvements are expected to be minimal.

Ongoing Work:

- A $2 million project to address Shaft 9 issues associated with inspection and repair of piping and other components in the access shafts is currently in the FY14 CIP and scheduled for July 2015.

Dorchester Tunnel

The Dorchester Tunnel is a 10' diameter tunnel that extends southward from Shaft 7B to Shaft 7D in Dorchester. The Dorchester Tunnel was constructed in 1976. Redundancy for the Dorchester Tunnel still requires use of emergency backups like the Chestnut Hill Reservoir and Emergency Pump Station which are expected to require a boil water order if use is required. The planned use of surface mains to allow emergency backup from Shafts 7 or 7B is not complete at this time. This work was always part of the Chestnut Hill Connecting Mains Project which has now been folded into the southern portion of the larger redundancy project (see chapter 8). When this work is complete, it will improve and strengthen surface piping to accommodate a problem with the Dorchester Tunnel or with the City Tunnel prior to the Dorchester Tunnel. The FY13 CIP proposes that this work begin in FY18.

7.5 Standby Aqueducts and Facilities

The following section discusses those parts of the system not currently in active use and potentially available for emergency operations.

General Information: Public Access

In March 2012, the MWRA Board of Directors approved the *Policy and Guidelines for Authorized Public Access to Water Supply Lands Under the Care and Control of the MWRA*. This policy allows MWRA to enter into revocable agreements with local communities, public agencies and/or non-profits to allow certain limited public access on specific MWRA controlled water supply lands. The policy specifically addresses the aqueduct alignments for the Cochituate, Sudbury, Wachusett and Weston Aqueducts and the lands around Weston and Norumbega Reservoirs. In past years, MWRA has, in some cases, established formal agreements with host communities using MWRA's 8(m) permit system or Memorandum of Agreements. Each location has unique characteristics and customized 8(m) permits allow the flexibility to address those characteristics within the framework of the broader policy. MWRA will continue to address unauthorized uses as necessary. However, authorized use of lands which are not part of the active water supply system allows MWRA to focus staff resources on the active system and enhances system security and safety through the development of partnerships with the communities.

Wachusett Aqueduct

As part of the preparation for construction of the MetroWest Water Supply Tunnel, rehabilitation of the Wachusett Aqueduct was completed in 2002. The intent was to ensure that the Aqueduct could be the single transmission facility during the winter of 2003-04 when the Cosgrove Tunnel was taken out of service for connection to the CWTP. In addition to structural rehabilitation of portions of the aqueduct, a pressure reducing structure was constructed at elevation 281.5 BCB to prevent over pressurization of the aqueduct during operation and a shotcrete liner was applied to the inside to reduce head loss as much as possible and maximize flows through the aqueduct. The rehabilitated aqueduct was found to be capable of approximately 240 MGD but cannot operate with any internal pressure which limits the delivery water gradient to elevation 281 BCB.

Subsequent inspection of the Cosgrove Tunnel identified a need for future repair of the Tunnel and the long-term need to have the Wachusett Aqueduct available for use during those times when the Cosgrove Tunnel would not be available. The 2006 Master Plan recommended inclusion of $100 million as a placeholder for the provision of redundancy for the Cosgrove Tunnel. As part of the broader Concept Plan for Transmission system redundancy, the consultant considered two main alternatives: 1) Use the existing gravity Wachusett Aqueduct and construct a new emergency pump station at the CWTP site to boost the raw water in the Aqueduct to meet the required hydraulic grade line for the CWTP; and, 2) Pressurize the Wachusett Aqueduct through installation of a pipe within the existing structure with various pipe diameters considered.

Analyses showed that a pressurized Aqueduct could deliver more water to the plant, however, the additional cost of pressurization was over $100 million more than construction of a pump station. The 240 MGD capacity would allow for unrestricted supply for at least 8 months in the lower-demand fall/winter/spring period during a planned or emergency shutdown of the Cosgrove Tunnel. In January, 2012, the Board of Directors approved the award of a design contract for the pump station.

Open Channel (see discussion of bridges and roads)

Wachusett Aqueduct Structures and Facilities

Wachusett Dam Upper Gatehouse

This structure is part of the dam structure and is the intake for the former Wachusett Power Station (Lower Gatehouse). The building houses operators for valves at three reservoir intake levels as well as screens and stop logs. The upper two intakes discharge to four vertical wells which are connected to 48” discharge pipes running horizontally 113’ below the floor. These pipes flow directly to the lower gate house for discharge to the Wachusett Aqueduct or to the Nashua River. Some level of repairs to reduce long-term building deterioration will ultimately be required.

The Wachusett Power Station and Lower Gatehouse

This facility is located at the base of the Wachusett Reservoir Dam. This is the intake and gate house for the Wachusett Aqueduct and the bypass to the Nashua River. It is a granite superstructure and a concrete substructure with a copper sheet roof. The substructure is separated into 4 main chambers of which 2 feed the Wachusett Aqueduct. The building footprint (105' x 74') includes a three story office area and a large open room with four generators. The heating system is adequate for the abandoned offices but not capable of maintaining heat in the main turbine floor area. The brick work in the turbine room is exhibiting deterioration. This facility was retired from active service in the 1960's. Repairs will be necessary to prevent further building deterioration. The river valves and cross-over piping were not replaced in 2003 when mechanical rehabilitation was completed. These pipes and valves are deteriorated and should be replaced or rehabilitated.

Projects in the FY14 CIP:

Because most of the building deterioration issues are related to moisture damage and the difficulty in maintaining heat within the building, two ongoing CIP projects have been identified. An initial project to replace the leaking roof, gutters and deteriorating windows and doors as well as to repair and seal the building masonry is scheduled to begin in 2014 at an estimated cost of $2.2 million. A second project to investigate geothermal heat to moderate building temperatures and slow building decay has also been added to the CIP for FY2019 with funding at $200,000. A project to rehabilitate Chamber 4 piping is also projected to start in 2019 at an approximate cost of $1 million.

Assabet River Bridge and Siphon

The original Wachusett Aqueduct crossing of the Assabet River was done by use of an aqueduct bridge similar in style to the Echo Bridge on the Sudbury Aqueduct crossing of the Charles River. Due to deteriorated condition and leakage, a siphon was added under the Assabet River and all flow now passes through the siphon. The aqueduct bridge structure remains and will require masonry rehabilitation and other remedial work as it ages.

Other Roads and Bridges

The portion of the Wachusett Aqueduct along the open channel includes a number of roads and bridges that were initially constructed by predecessor agencies (see Table 7-4). Besides Wachusett Aqueduct, additional bridges cross within the Sudbury Reservoir system and at the Weston Reservoir. The list of roads/bridges identified by Western Operations is included in Table 7-4 below. MWRA has performed maintenance on some of these structures but ownership and maintenance responsibilities need to be better delineated. To date, costs have generally been absorbed within the CEB expenditures but more significant costs could be incurred over time as the structures age.

Table 7-4

Bridge Location @	***Associated With***
Bridge Near Hultman Intake Dam	Wachusett Aqueduct Open Channel
Carroll Water Treatment Plant	Wachusett Aqueduct Open Channel
Ward Road	Wachusett Aqueduct Open Channel
Route 495	Wachusett Aqueduct Open Channel
Johnson Road	Wachusett Aqueduct Open Channel
Northborough Road	Wachusett Aqueduct Open Channel
Route 30	Wachusett Aqueduct Open Channel
Lynbrook Road	Wachusett Aqueduct Open Channel
Deerfoot Road	Wachusett Aqueduct Open Channel
Parkerville Road	Wachusett Aqueduct Open Channel
Middle Road	Wachusett Aqueduct Open Channel
Stonybrook	Sudbury Reservoir
Route 30	Sudbury Reservoir
Route 9	Foss Reservoir (Framingham #3)
Salem End Road	Foss Reservoir (Framingham #3)
Fountain Street	Brackett Reservoir (Framingham #2)
Winter Street	Stearns Reservoir (Framingham #1)
Ash Street	Weston Reservoir (Open Channel)

Recommendation

- Recommend that staff request clarification from the Law Division on the ownership and maintenance responsibilities for bridges and roads across the Open Channel and at other locations as determined by Western Operations.

Additional structures along the Wachusett Aqueduct include the circular Rattlesnake Hill Access Shaft and the Linden Street Gatehouse. Rattlesnake Hill may have been used for personnel access to the aqueduct. The shaft is offset to the side of the aqueduct, which lies approximately 25-30 feet below the building's first floor. The building has deteriorated significantly over time and is currently blocked off for safety reasons.

Weston Aqueduct

The Weston Aqueduct was completed in 1903 and begins at the Sudbury Dam near Shaft 4 and continues from there to the west side of the Charles River in Weston near the intersection of I-128 and the Massachusetts Turnpike. The aqueduct is approximately 12 miles in length and was constructed of concrete and brick masonry. It varies between 9 and 12 feet in height and 10-13 feet in width. The Weston Aqueduct was originally designed to bring water from the Sudbury Reservoir but due to deteriorating water quality conditions in the Sudbury in the 1960's was last operated by a pressure reduced feed from the Hultman or through the hydropower turbine at Shaft 4. The use of the open Weston Reservoir was eliminated in the early 1990's by replacing its flow from pressure reduced connections from the High Service.

The Weston Aqueduct has two main sections, the first intended to get water from the Shaft 4 area to Weston Reservoir and the second being to bring water from the reservoir to the Weston Terminal Chamber where low service distribution begins via the Weston Aqueduct Supply Mains (WASM) lines. In between the two aqueduct sections, the flow has to pass through the open Weston Reservoir. This aqueduct still provides emergency redundancy in a failure scenario which interrupts flow of both MetroWest and Hultman facilities since it can convey water from the Sudbury Dam vicinity all the way to supply the Low Service tanks at Loring Road if necessary. Temporary disinfection and a boil water order would be required in such a scenario

Projects in the FY14 CIP:

- A project to inspect the Weston Aqueduct is included in the FY14 CIP at a cost of $150,000 to be done between July 2015 and March 2016.

Weston Aqueduct Structures and Facilities

Also located at Shaft 4 is the Aqueduct transfer power station and connecting piping. The original building was constructed around 1899 and the Weston Aqueduct was fed by three 60-inch diameter pipes from the Sudbury Dam Gatehouse. Around 1985, the facility was modified for hydropower generation. Given that the Weston Aqueduct is no longer in routine operation, this facility is inactive.

In 2004 repair work was undertaken on the Ash Street Bridge in response to a routine inspection conducted by DCR. Repairs included replacement of deteriorated concrete on the underside of the bridge arch, repointing of the stone masonry mortar on one side, and sealing capstone joints under the bridge rail. In addition, a raised bituminous asphalt sidewalk was constructed over the bridge to provide safer access and crossing by pedestrians in the Weston Reservoir area.

Four siphon structures (#1, #2, #3, #4) exist along the Weston Aqueduct. These buildings are all approximately 21’ x 21’ and have no electricity, heating or plumbing. At one of the siphon locations, i.e. the Sudbury River crossing, the aqueduct crosses the river with two barrels, one piped under the river and one which is an 84-inch free standing pipe bridge over the river. These facilities are currently in good condition but may require rehabilitation in the future.

The Weston Reservoir Terminal Chamber is located at the terminus of the Weston Aqueduct where it becomes a section of open channel upstream of the open reservoir. The west wall of the building sets on the Aqueduct arch. Stoplogs can be set in place along the outlet wall to allow maintenance within the part of the aqueduct affected by reservoir backwater.

The Weston Aqueduct Screen Chamber is located on the Weston Reservoir Dam at the beginning of the lower aqueduct section and provides screening of the flow from the Weston Reservoir to the Weston Aqueduct. This is an older facility with some deterioration. The Weston Reservoir Headquarters and Chlorine Building formerly provided chlorine and ammonia storage and delivery equipment for the Weston Aqueduct.

The Weston Aqueduct currently ends at the west side of the Loring Road tanks and is connected via an air gap to the Loring Road piping. This allows use of the aqueduct if necessary to feed the tanks or Low Service pipes in an emergency.

The Weston Aqueduct lower terminal chamber lies at the former discharge end of the Weston Aqueduct just east of the Loring Road tanks. When in operation, the building substructure was normally flooded with water entering from the aqueduct termination point on the west wall of the facility. This facility was disconnected from the active water system when the Loring Road tanks were completed in 2002. The building currently provides storage for site maintenance.

Projects in the FY14 CIP:

- Rehabilitation of the Ash Street sluice gates is scheduled to be done in January 2016 at an estimated cost of $1 million.

Sudbury Aqueduct and Associated Structures and Facilities

The Sudbury Aqueduct was completed in 1878 and extends from Framingham Reservoir #1 to the Chestnut Hill area in Boston. It is a somewhat smaller diameter concrete and brick masonry gravity aqueduct (with a typical cross section of 7’8” high by 9’ wide). It was primarily constructed using cut and cover methods but has several tunnel segments, two aqueduct bridges and a siphon interspersed to address localized conditions. Surface pipelines connect it to the Chestnut Hill Pump Station and the Chestnut Hill Reservoir. It was designed to carry 90 MGD and was originally used to convey water from Framingham Reservoirs 1, 2, and 3 and indirectly from the Sudbury Reservoir or the Hultman Aqueduct via Reservoir No. 3. Reservoirs 1 and 2 were bypassed in the 1920’s for water quality reasons by connecting the Reservoir 3 gatehouse to the aqueduct via two 48-inch pipes. The Sudbury Aqueduct and ancillary facilities are important legacy facilities both because they provide critical back-up but also because the system provides key right-of-way for potentially addressing future system needs. The proposed pressurization of a portion of the Aqueduct as part of redundancy planning options illustrates this well.

The Sudbury Aqueduct was an essential element of serving the Southern High and Southern Extra High prior to completion of the Dorchester Tunnel in 1974. The water quality of the Sudbury system no longer met standards so routine use was discontinued as soon as the new Dorchester Tunnel allowed, relegating the Sudbury Aqueduct to emergency back-up status. However, it is a particularly significant asset in that regard since it goes all the way into the Chestnut Hill area. In May, 2010 the Aqueduct was brought on line to supply water to the Chestnut Hill reservoir.

MWRA staff most recently investigated the Aqueduct thoroughly in 2002 to determine its physical condition and to determine the location, extent and characterization of sediment in the Aqueduct. (Sudbury Aqueduct Condition Assessment with Interior Rehabilitation Recommendations, June, 2004). In 2005-2006, consultant staff undertook follow-up investigations for the MWRA of the aqueduct condition with particular effort on the known hazardous waste sites, the clogged Rosemary Brook siphon and the areas where previous examinations had noted structural problems.

External investigations included a walk-over of the entire Aqueduct length and inspection of critical structures including approximately 46 culverts; approximately 45 manholes, two 500-foot bridge structures, one 1,800 foot siphon including two chambers and siphon blow-off valves, four waste weir culverts and all areas identified as having internal defects. Internal inspections focused on those areas identified as having invert heaving and possible undermining and areas identified as having a large aperture crown crack (a particular soft ground tunnel segment).

Crack in Crown of Pipe

Leak Boil in Floor

The Sudbury Aqueduct has four waste weirs located along its length (A, B, C, D). All of these structures serve as overflow release points for the aqueduct when it is in service and they allow small streams or brooks to transverse the aqueduct. Structures at all four locations are single story granite and brick structures approximately 15' x 20' in size with slate roofs. None of the structures have electricity, heat or plumbing. Waste Weir A is where Course Brook transverses the aqueduct; Bacon's Brook Waste Weir B allows Davis Brook to transverse the aqueduct; Waste Weir C is where Fuller's Brook transverses the Aqueduct and Waste Weir D allows an unnamed drainage way to pass underneath the Aqueduct. When inspected during 1995-96, over $135,000 in recommended deficiencies were identified including significant structural and safety improvements. Some of these deficiencies were fixed as part of more recent sluice gate rehabilitation.

The Rosemary Brook siphon crosses a wide low area by use of pressurized 48-inch pipes. The East and West Rosemary Brook Siphon Chambers are twin facilities that transition Sudbury Aqueduct flow from a normal aqueduct cross section conduit to two pipelines and then back into a normal aqueduct structure. These structures were cleaned by MWRA staff to ensure availability during an emergency occurrence. The siphon chamber facilities are constructed in a similar fashion with the exception being a circular tower within the west Chamber. These structures have been recently inspected and fencing has been used to provide protection from deteriorated structures.

MWRA has care and control of the Echo Bridge (1878) which spans the Charles River from Newton Upper Falls to Needham. The structure contains a water conduit and essentially functions as a pipe bridge over the river. The surface has a heavily used pedestrian bridge and is located in Hemlock Gorge, a DCR owned park. Echo Bridge was included on the National Register of Historic Places in 1980, prior to the rest of the Waterworks system. MWRA has repointed the brick surfaces of the structure in the late 1980's and the masonry is currently in good condition.

The handrails along the top of the 500' pedestrian bridge are original, made of cast iron and have been determined to be in poor condition. In 2006, the MWRA installed interim safety fencing in front of the hand railings on both sides of the bridge as a protective measure. Since the hand rails are historic and must be repaired or replaced, MWRA has offered to work with elected officials and other interested parties to identify potential sources of outside funding. Similar to Echo Bridge, Waban Arches Bridge also has original cast iron railings that are seriously deteriorated and similar safety fencing has been installed there as well.

The Farm Pond Gatehouse and Inlet Chamber are located in Framingham and historically, provided access to the Aqueduct. In addition, the Inlet Chamber provided a connection to Farm Pond (stop-logs) and the Gatehouse provided flow control through 4' x 4' sluice gates and screening. These facilities are in seriously deteriorated condition, in danger of collapse and can longer be accessed in any fashion due to safety considerations. Given the poor condition of these structures, a decision should be made whether the sluice gates are necessary at this location and whether access to the aqueduct could be maintained in another manner. The 1995 condition assessment recommended that access to the aqueduct be capped at this location. Although, as all of the Sudbury Aqueduct facilities, these two structures are on the National Register, coordination should occur with appropriate staff to determine if these facilities can be fully documented and taken down.

Projects in the FY14 CIP:

- Phase 1 and Phase 2 (combined estimated cost of approximately $2.5 million) of Short-Term Repairs are scheduled to begin in July 2014 in order to better prepare the Aqueduct for emergency activation if necessary. However, the ongoing redundancy concept planning work for the Metropolitan System will review the proposed repair work and recommend any changes to the scope of work and/or the schedule.

- An evaluation of the Rosemary Brook Siphon Gatehouse Buildings is included in the Sudbury Aqueduct Pressurization & Connections: Alternatives Analysis and MEPA Review contract. The intent of this work is to evaluate the condition of the historic structures and make recommendations for rehabilitation or removal in accordance with applicable requirements.

Southern Sudbury Transfer system

In the 1930's, MDC constructed a temporary water transfer piping system to act as a drought supplement to the existing Sudbury system reservoirs while Quabbin was being constructed. The transfer piping included an open channel and 24" pipe to transfer water from Whitehall Reservoir to Hopkinton Reservoir, a 30" pipe from Hopkinton Reservoir to Sudbury Reservoir, a transfer pumping station for the 30" pipe in Cordaville and a 24" pipe from Ashland Reservoir to Reservoir 1. This system was only needed until Quabbin was completed and was never utilized again. The pump station was demolished and all of the southern Sudbury system reservoirs were transferred to DEM (now DCR). The remaining issue is that the pipelines still exist and may become an issue if there is a collapse in the public way or if the pipeline causes property damage due to inadvertent leakage. MWRA has no plans for reuse but there may be a cost of stabilization (e.g. filling the pipes to prevent collapse) prior to disposition as surplus.

Norumbega Facilities

The Norumbega Open Reservoir and associated back-up facilities remains as part of the emergency back-up system. However, structures that were in daily use prior to the construction of the Norumbega Covered Storage Facility coming on line are no longer used or will be phased out as the final interconnections are made between the Hultman and new facilities.. These include the Norumbega Reservoir Gatehouse and Screen Chamber through which the Hultman Aqueduct passes. Ongoing and future work will disconnect this portion of the Hultman and redirect flows around the Gatehouse. It will be possible to reconnect the Hultman to the Open Reservoir in the event of an emergency. In the event chlorination is required during an emergency; temporary equipment will be brought to the site. No major expenditures are anticipated at this location.

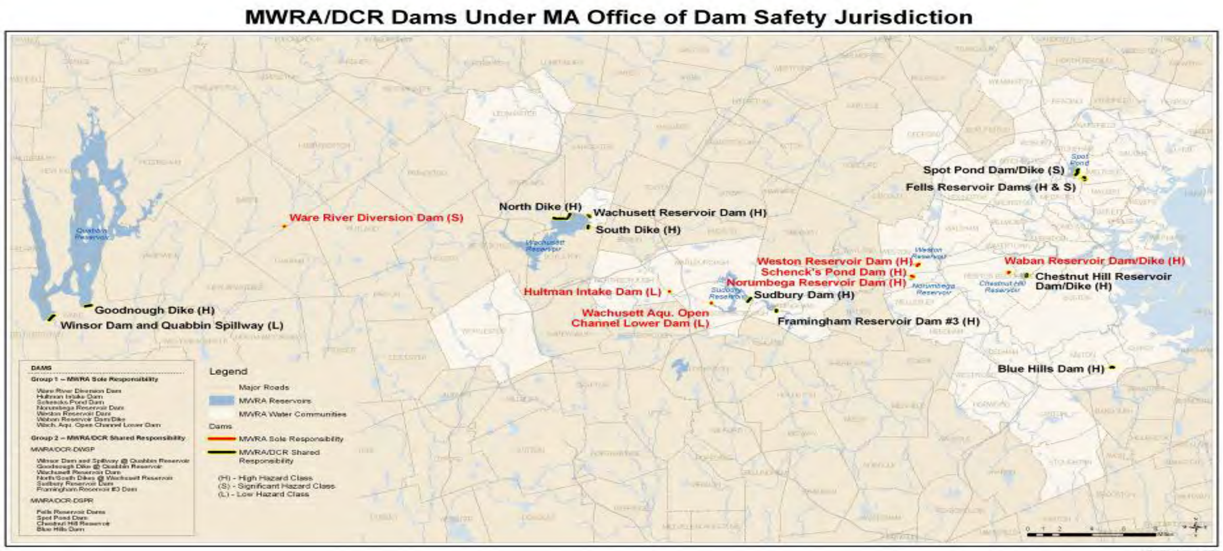
7.6 Dams

Overview and Responsible Parties

A list of water supply dams is shown in Table 7-5. The original split of dam responsibilities in the MDC/MWRA Memorandum of Understanding was intended to make MWRA responsible for only the dams at distribution reservoirs. The MOU also specifically called out that MWRA would be responsible for Sudbury Reservoir and Reservoir 3 due to the proximity to MWRA offices.

Given the importance of the major reservoir dams to the water supply infrastructure, the MOU was amended on April 27, 2004 to make MWRA directly responsible for the source reservoir dams, in addition to the emergency distribution reservoir dams. DCR continues to be responsible for tributary dams and inactive source dams such as Reservoirs 1 and 2 in the Sudbury system. The Commonwealth of Massachusetts retains ownership of all the dams. These dams are presented geographically in the following map.

Figure 7-7



Dam Condition Assessments

Under the Project Prioritization Assessment, there are 26 individual dams across 18 facilities for which MWRA has responsibility. Some reservoirs have several dams and dikes creating the named impoundment (e.g. Norumbega Reservoir has Dams 1, 2, 3, 4 and East Dike). All of these are jurisdictional under the Office of Dam Safety regulations 302 CRM 10:00. MWRA began conducting Phase I dam safety inspections under these regulations in 2005 and continues to conduct biennial inspections at High Hazard Class dams, 5-year inspections at Significant Hazard class dams, and 10-year inspections at Low Hazard class dams.

While most dams remain in "Fair" to "Satisfactory" condition due to both their robust construction and periodic maintenance over time, the inspections since 2005 have resulted in a number of deficiencies (Table 7-5) under the current dam safety regulations that required attention.

Table 7-5
List of water supply dams

Location	Name	Description	Capital Needs
Quabbin area	Winsor Dam	1930s, Earthen dam	**Toe and surface drain repair work completed**
	Goodnough Dike	1930s, Earthen dam	**Toe drain work**
	Quabbin spllway	1930's, Masonry structure	**Repointing Completed**
Wachusett area	Wachusett Dam	1906 Masonry Dam and spillway	**Spillway work, repointing Completed**
	North Dike	1906 Earthen dam	**Tree clearing underway**
	South Dike	1906 Earthen Dam	**Tree clearing**
Sudbury System	Sudbury Res	1898 Earthen dam with core wall, masonry spillway	**Riprap resetting, long term repointing**
	Reservoir 3	1898 Earthen dam with core wall, masonry spillway	**Tree clearing, grading, riprap Completed**
	Reservoir 1	1878 Earthen dam with core wall	**DCR responsibility**
	Reservoir 2	1882 Earthen dam with core wall	**DCR responsibility**
Dist. Reservoirs	Norumbega	1940 Earthen with core wall, multiple dikes	**Minimal**
	Schenk's Pond	1940 Earthen with core wall, multiple dikes	**Minimal**
	Weston	1903 Earthen dam	**Tree clearing, parapet wall construction Completed**
	Spot Pond	1901 Earthen with core wall, multiple dikes	**Tree clearing, armoring Dam #1 Completed**
	Fells	1899 Earthen with core wall, multiple dikes	**Tree clearing Completed. Inspection of LLO needed**
	Chestnut Hill	1868 Earthen dam	**Riprap, grading**
	Waban Hill	1900 Earthen dam	**Riprap, grading**
Ware River	Coldbrook	1931 Masonry dam	**Long term repointing Completed**
Hultman Intake	Forebay channel	1940 Masonry dams	**Minor**
Southboro Open channel	Cascading dams to Sudbury Res.	1898, multiple masonry dams	**Long term repointing, riprap**
Defunct dams	Fisher Hill	Inactive and empty	**N/A**
	Nash Hill	Inactive and empty	**N/A**
	Blue Hills	Dewatered for tank construction	**Masonry dam repointing and grouting of cracks**

Reports from these inspections are delivered to the MA Office of Dam Safety where deficiencies are monitored for corrective action. MWRA assigns the needs to either a Maintenance or Capital level program. Since 2005 many improvements were completed with remaining projects incorporated into MWRA's CIP.

The present condition assessment as of FY12 is provided in the Table 7-6:

Table 7-6

MWRA Water Supply Dams Inspection Program -															
Insp. Cycle (yr)	Dam Name and Location	Note	Year Completed	Construction	Structural Height (ft)	Storage (MG)	ACOE Class.	Hazard Class.	Previous Phase I Inspection	Recent Phase II Studies	Dam Condition resulting from recent inspection	Condition	2010 Phase I Inspection	Condition	Next Phase I Inspection
2	Winsor Dam, Belchertown, MA	1	1939	Earthen	170	412,000	Large	High	8/20/2008		SATISFACTORY	Satisfactory	8/25/2010	Good	8/25/2012
	Goodnough Dike, Ware, MA	1	1938	Earthen	135			High			SATISFACTORY	Satisfactory		Good	
	Quabbin Spillway	1	1938	Masonry	10			Low			SATISFACTORY	Satisfactory		Good	
5	Ware River Diversion Dam, Barre, MA	2	1931	Masonry	38	Run of River	Intermediate	Significant	8/13/2008	FY 07 H&H	SATISFACTORY	Satisfactory	n/a		8/10/2013
2	Wachusett Reservoir Dam, Clinton, MA	1	1905	Masonry	114	65,000	Large	High	8/21/2008		SATISFACTORY	Satisfactory	8/21/2010	Good	8/23/2012
	Wachusett Reservoir North Dike, Clinton, MA	1	1905	Earthen	22		Large	High			SATISFACTORY	Satisfactory		Satisfactory	
	Wachusett Reservoir South Dike, Boylston, MA	1	1905	Earthen	45		Large	High			SATISFACTORY	Satisfactory		Fair	
10	Open Channel Lower Dam, Southborough, MA	2	1880s	Masonry	18.5	8	Intermediate	Low	4/18/2008	FY 07 H&H	FAIR	Satisfactory	n/a	Satisfactory	4/18/2018
2	Sudbury Dam, Southborough, MA	1	1898	Earthen	84	7,200	Large	High	4/18/2008	FY 07 H&H	SATISFACTORY	Satisfactory	8/27/2010	Satisfactory	8/27/2012
2	Framingham Reservoir #3 Dam, Framingham, MA	1	1890s	Earthen	29	1,500	Large	High	4/18/2008	FY 07 H&H	SATISFACTORY	Satisfactory	8/27/2010	Satisfactory	8/27/2012
2	Norumbega Res Dam, Weston, MA	2	1940s	Earthen	42	163	Large	High	4/17/2008	FY 07 H&H	SATISFACTORY	Satisfactory	8/20/2010	Satisfactory	8/20/2012
2	Schencks Pond Dam, Weston, MA	2	1940s	Earthen	22	43	Intermediate	High	4/17/2008		SATISFACTORY	Satisfactory	8/20/2010	Satisfactory	8/20/2012
2	Weston Reservoir Dam, Weston, MA	2	1903	Earthen	40	360	Intermediate	High	4/17/2008	FY 07 H&H, Inundation Mapping	FAIR	Fair	8/20/2010	Fair	8/20/2012
5	Spot Pond Dam 1, 4 and 5 , Stoneham, MA	1*	1899	Earthen	13	2,500	Large	Significant	4/17/2008	H&H, Inundation Mapping	FAIR	Satisfactory	n/a		4/17/2013
2	Fells Reservoir Dam 2,3,4, Stoneham, MA	1	1898	Earthen	#2=12, #3=25,#4=12,#6=17,#7=4,#8=48	63	Intermediate	Significant or High	4/17/2008	FY 07 H&H, Inundation Mapping	FAIR	Fair	9/15/2010	Fair	9/15/2012
2	Fells Reservoir Dam 6,7 and 8, Stoneham, MA											Fair		Satisfactory	
2	Waban Hill Reservoir Dam, Newton, MA	2	1900	Earthen	24	5	Intermediate	High	4/18/2008	FY 07 Inundation Mapping	SATISFACTORY	Fair	8/24/2010	Fair	8/24/2012
2	Chestnut Hill Dam/Dikes, Boston/Newton, MA	1*	1860s	Earthen	19	413	Large	High	4/17/2008	FY 07 Inundation Mapping	SATISFACTORY	Satisfactory	8/24/2010	Satisfactory	8/24/2012
10	Hultman Intake Dam	2	1940s	Masonry	12	8	Small	Low	Nov. 2005		FAIR	Satisfactory	n/a		Nov. 2015
2	Blue Hills Dam	3						High	?			Satisfactory	9/2/2010	Satisfactory	9/2/2012

Notes:

Condition categories range: Poor, Fair, Satisfactory, Good.

Upgrade

Downgrade. Deficiencies addressed spring 2012

1 - MWRA/DCR-DWSP shared Capita/operational responsibility. * DCR State Parks
2 - Sole MWRA Capital/operational responsibility
3 - DCR State Parks after 2012

These jurisdictional dams require dam safety inspections by a licensed dam safety inspector, based upon their Hazard class discussed above. The next inspections are scheduled for FY13.

Long term dam maintenance activities are largely determined by the type of dam structure. Tree removal and brush control is a factor on all dams but the earthen dams are more likely to require greater attention to vegetation maintenance and close monitoring of surficial issues such as animal burrows, erosion and drainage (e.g., toe drain conditions). The masonry dams will need repointing at approximately twenty-year intervals. Some minor seepage and leakage is to be expected at all dams and this must also be monitored for changes in rate and water quality (e.g., sediment in seepage could mean internal erosion). Over time settlement occurs and all dams may need periodic resetting of riprap as well.

<u>Quabbin Reservoir (Winsor Dam, Goodnough Dike, Quabbin Spillway)</u>

At the Quabbin Reservoir, the major impounding dam structures are Winsor Dam, Goodnough Dike and Quabbin Spillway, all of which are over 70 years old

In 2007, MWRA completed upgrades to the Winsor dam internal drainage system and installation of 8 new vibrating wire piezometers.

Piezometer installation at Winsor Dam

At Quabbin Spillway, previous Phase I inspections reported mortar loss in many joints on the upstream and downstream sides of both the upper and lower sections of Quabbin Spillway. In 2010 during an abnormal dry fall season, the reservoir elevation dropped several feet revealing significant mortar loss and voids in the upstream side of the spillway. By late fall 2010 MWRA had completed repointing and injection grouting of Quabbin Spillway correcting all noted deficiencies.

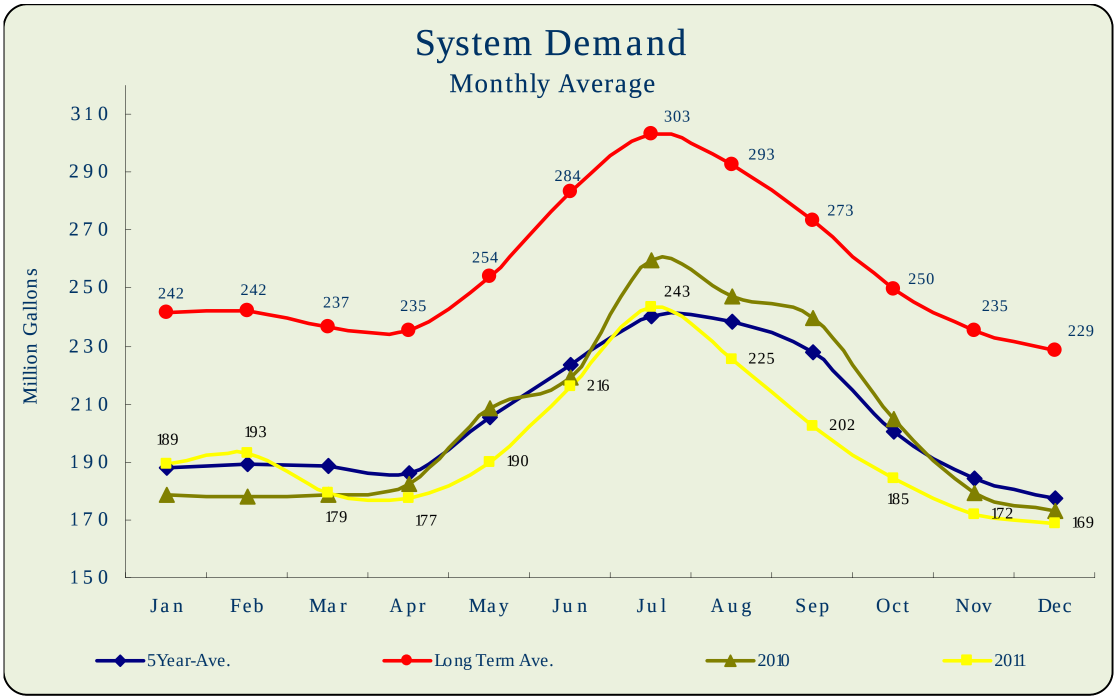
Major voids in upstream side of Quabbin spillway

Major voids repaired, injection-grouted and mortared

Quabbin Spillway

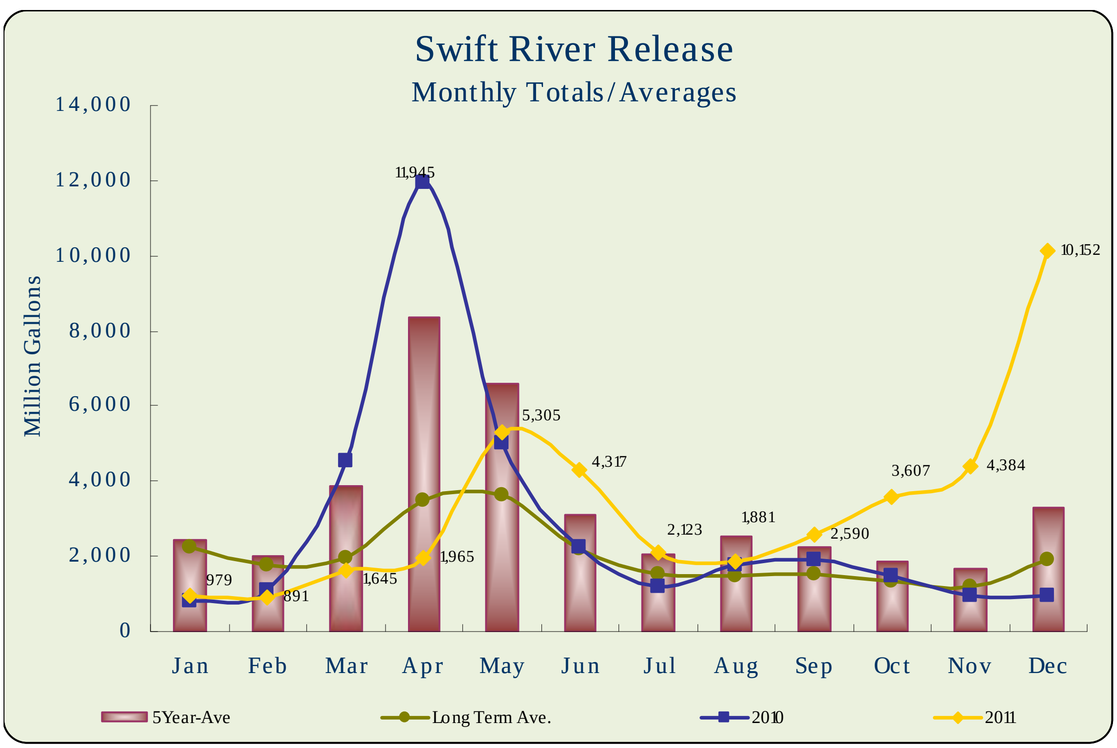
Reduced consumer demand, water saving measures, and above average precipitation over the last decade has resulted in high Quabbin elevations for several years running.

Figure 7-8



This has created operational concerns due to more frequent and longer-term spilling (see Swift River Release) and going into winter and spring seasons with minimal freeboard. During hurricane season or spring runoff conditions, a full-to-the-brim reservoir is not operationally desired and could result in greater downstream flooding problems due to uncontrolled spilling.

Figure 7-9



Since there is no structural means for MWRA to remove[2] excess water from Quabbin Reservoir, a preliminary design study will be performed to assess lowering the bottom sill of the lower Quabbin Spillway with installation of a mechanical gate to allow greater operational seasonal elevation control.

In 2011, an internal assessment of the Goodnough Dike toe drain system was completed. Some immediate repairs were completed in-house by DCR-DWSP. However, as it was observed in the 2010 Phase I Inspection, and corroborated by the 2011 Appurtenant Structures internal assessment, the downstream Beaver Brook impoundment is creating localized backwater conditions in portions of the Dike's blanket and toe drain. Years of beaver activity and consequent sedimentation and vegetation growth in the Beaver Brook drainage have adversely affected proper drainage from the Dike area. MWRA will perform a conceptual design study in FY 13 to assess options for restoring proper drainage to this area. This will likely result in a capital project such as dredging and/or installation of drainage piping or a surficial channel.

Wachusett Reservoir (Wachusett Dam, North Dike, South Dike)

Substantial improvements have been made to the Dams and Dikes at Wachusett Reservoir since 2005. In 2007, to address deficiencies in passing the regulatory Spillway Design Flood (SDF), the 100 ft. lower stop log-controlled spillway was demolished, lowered two ft. and a mechanical crest gate was installed for greater operational elevation control, The 350 ft. upper masonry spillway was cleaned and repointed. The project investment was $5.4 M.

Old stop log bays, sill at 392' BCB

Stainless steel mechanical crest gate, new sill at 390' BCB

[2] Seasonal Quabbin Transfer (Shaft 12), CVA demand and WPS releases to the Swift River amount to relatively insignificant releases considering the massive volume of Quabbin. An additional structural means to move water is desired.

The downstream area saw the creation of an auxiliary spillway discharge channel to handle SDF discharge and the left abutment was raised and armored to prevent erosion of the earthen dam at the SDF.

East Berm created along left abutment

East Berm armored

During the spillway project, spoils from the excavation were used to structurally reinforce the North Dike at a historically weakened area. This area was stripped back, benched and backstopped with rock spoil. The area was re-graded to original slope conditions.

North Dike structural improvements

Also in 2007 it was discovered that PCB caulking used in the Promenade walkway joints in the mid 1960's had leached into concrete and was carried by runoff down the face of Wachusett Dam where it penetrated efflorescence and mortar. Under US EPA remediation guidance, the Promenade walkway was demolished with the PCB concrete wastes sent to special landfills. A new walkway with improved drainage was constructed. Total investment $2.22 M.

Promenade with PCB contaminated areas marked in red.

Rebuilt Promenade

In 2009-2010, the next major remediation project was completed to remove the PCB contamination from efflorescence and mortar on the face of Wachusett Dam, followed by repointing and high-pressure power washing of the dam face. Additionally, this project also included the installation of eight new piezometers to replace failed and unserviceable ones. The total investment in this project was $2.441 M.

PCB-contaminated efflorescence and mortar

Wachusett Dam, post PCB remediation, repointing and cleaning

Previous Phase I Dam Safety Inspections have noted that widespread tree growth on Wachusett Reservoir North and South Dikes is a regulatory deficiency under the 302 CMR 10.00 and the MA Office of Dam Safety's "Policy on Trees on Earthen Dams," which prohibits this condition.

Tree growth on earthen dams can lead to impounded reservoir water penetration of decayed root pathways leading to "piping" – a phenomena which can cause internal erosion and ultimately failure of the dam. Uprooted trees can also create dam safety problems, and widespread tree and vegetation growth and forest litter on a dam slope prevents optimal inspection for early signs of problems such as slumps and seeps. Trees must be cut and have the stumps pulled to remove the bulk of root matter. The stump voids are then backfilled and compacted, and seeded for uniform grass cover.

Stump removal from dam

Stump void fill and compaction, prior to final loaming and seeding

MWRA allocated $500,000 in the CEB for FY12 for South Dike. The work is expected to be completed by June 2012. A similar tree growth condition exists on sections of the much longer North Dike. This work was initiated earlier than anticipated and will be completed in 2012 at an estimated cost of $350,000.

Dam Projects Included in the FY14 CIP:

- Allocate $1 million in FY 15-16 time period for Quabbin's Goodnough Dike/Beaver Brook drainage rehabilitation. This project will restore proper drainage to the downstream discharge location of the Goodnough Dike toe drain system. Continued flooding of this system due to downstream conditions could lead to internal problems within the dam.

- A project to provide final design, ESDC/RI and construction for the removal of the Oakdale Dam adjacent to the Oakdale Pump Station is included in the FY14 CIP. The removal of the dam will help landlocked fish in the Wachusett Reservoir reach spawning grounds in the Quinapoxet River. The project cost is $950,000 and permitting is anticipated to begin in January 2014 and design work is scheduled to begin in July 2015.

Recommended Dam Projects

- Allocate $1.5 M for Quabbin Lower Spillway Improvements for FY19-23 time period

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for earthen dams.

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for masonry dams.

7.7 Summary of Recommended Transmission System Improvements

Staff recommends consideration for the FY14-53 timeframe of the following projects:

Redundancy projects:

- $1.5 million for recurring inspections (15 year intervals) to the Cosgrove Tunnel. This work should be seasonally scheduled and should begin in FY19.

Priority repair, rehabilitation and improvement projects:

- $8.6 million for Oakdale Phase 2 improvements which will incorporate remaining work at the Oakdale Power Station including building repairs and hydraulic control improvements. ($8.6 million)

- $7.5 million for dam-related projects, including ongoing long-term repairs to earthen and masonry dams ($6 million) and, Quabbin Lower Spillway Improvements ($1.5 million).

- Long-term, a study to consider the feasibility of the previously recommended Wachusett Bypass should be considered including alternatives, other than a bypass, to address potential Wachusett Reservoir contamination issues. A specific study is not recommended at this time but should be revisited during each master planning cycle.

- Recommend that staff request clarification from the Law Division on the ownership and maintenance responsibilities for bridges and roads across the Open Channel and at other locations as determined by Western Operations.

Table 7-7

Water Master Plan - Transmission System and Dams

Existing and Recommended Projects

Last revision 9/17/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF New Facility/System
RF/IC Replacement Facility/Increase Capacity
Opti Optimization
AP Asset Protection
Plan Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
7.01	2	Dam Safety Modification and Repairs - Construction	AP	623	60100_7211	2 years	421	ongoing-FY15	421				421
7.02	3	Oakdale Dam Removal - Design/ESDC/RI	Opti	623	60119_7347	4 years	200	FY16-19	157	43			200
7.03	3	Oakdale Dam Removal - Construction	Opti	623	60120_7348	2 years	750	FY17-18	750				750
7.04	2	Goodnough Dike Drainage Improvements	AP	623	60131_7370	2 years	1,000	FY15-16	1,000				1,000
7.05	1	Wachusett Aqueduct Pump Station - Design and Construction	NF	625	60090_7156 60091_7157	4 years	49,020	ongoing-FY17	49,020				49,020
7.06	1	Long Term Redundancy - Sudbury Aqueduct - MEPA Review and Design	NF/RF	625	60122_7352 60092_7159	14 years	55,524	ongoing-FY26	3,027	31,170	21,327		55,524
7.07	1	Long Term Redundancy - Sudbury Aqueduct - Slipline Construction	NF/RF	625	60093_7160	3 years	95,966	FY22-24		54,467	41,499		95,966
7.08	1	Long Term Redundancy - MetroWest Water Supply Tunnel/Sudbury Aqueduct Connection - Construction	NF	625	60107_7291	4 years	155,437	FY21-24		104,682	50,755		155,437
7.09	1	Long Term Redundancy - Chestnut Hill Final Connection - Construction	NF	625	60123_7353	3 years	11,079	FY21-23		11,079			11,079
7.10	2	Long Term Redundancy - Tops of Shafts Rehabilitation - Design and Construction	AP	625	60126_7356 60127_7357	6 years	5,501	FY22-27		344	5,157		5,501
7.11	2	Sudbury/Weston Aqueduct Repairs - Short Term Repairs Phases 1 and 2	AP	617	60076_7016 60110_7317	4 years	2,517	FY15-18	2,517				2,517
7.12	3	Sudbury/Weston Aqueduct Repairs - Ash Street Sluice Gates	AP	617	60130_7369	2 years	1,000	FY16-17	1,000				1,000
7.13	3	Sudbury/Weston Aqueduct Repairs - Weston Aqueduct Inspection	AP	617	60070_6947	1 year	150	FY16	150				150
7.14	1	Quabbin Transmission System - Oakdale Phase 1A Electrical - Design and Construction	AP	616	60103_7229 60104_7230	2 years	291	ongoing-FY15	291				291
7.15	3	Quabbin Transmission System - Ware River Intake Valve Replacement	Opti/AP	616	60108_7282	4 years	1,200	FY16-19	1,150	50			1,200
7.16	3	Quabbin Transmission System - CVA Intake Motorized Screens Replacement	AP	616	60112_7332	1 year	500	FY18	500				500
7.17	3	Quabbin Transmission System - Wachusett Lower Gatehouse Rehabilitation	AP	616	60113_7333	5 years	2,200	FY16-20	1,320	880			2,200
7.18	3	Quabbin Transmission System - Wachusett Gatehouse GeoThermal Heat	AP/NF	616	60136_7379	2 years	200	FY19-20		200			200
7.19	3	Quabbin Transmission System - Wachusett Gatehouse Chamber 4 Piping Rehabilitation	AP	616	60137_7380	2 years	1,000	FY19-20		1,000			1,000
7.20	3	Quabbin Transmission System - Oakdale Turbine Rehabilitation	AP	616	60135_7378	2 years	1,000	FY20-21		1,000			1,000
7.21	2	MetroWest Tunnel - Valve Chamber Modifications - Design and Construction	Opti	604	60072_6950 75525_7755	4 years	5,815	FY17-20	1,255	4,560			5,815
7.22	2	Metrowest Tunnel - Valve Chamber and Storage Tank Access Improvements	Opti	604	60109_7283	5 years	3,000	FY15-19	2,900	100			3,000

Table 7-7

Water Master Plan - Transmission System and Dams

Existing and Recommended Projects

Last revision 9/17/13

Prioritization

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2 Essential
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Project Types

NF New Facility/System
RF/IC Replacement Facility/Increase Capacity
Opti Optimization
AP Asset Protection
Plan Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

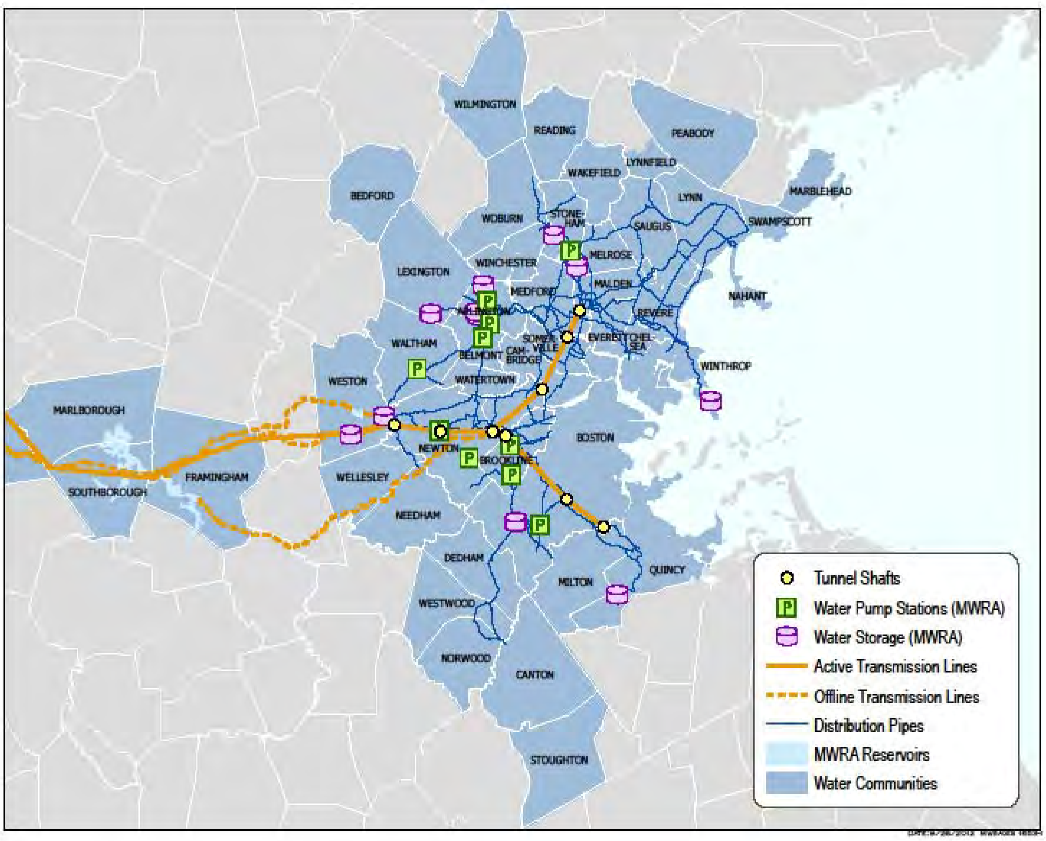
Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
7.23	2	MetroWest Tunnel - Shaft 5 Electrical Upgrade	AP/Opti	604	60128_7367	2 years	1,000	FY19-20		1,000			1,000
7.24	2	MetroWest Tunnel - Shaft 5/5A Surface Pipling Inspection and Restoration	AP	604	60129_7368	2 years	1,500	FY15-16	1,500				1,500
7.25	3	Winsor Station Pipeline - Quabbin Aqueduct TV Inspection	AP/Plan	597	60033_6277	5 years	2,806	FY19-23		2,806			2,806
7.26	2	Winsor Station Pipeline - Quabbin Aqueduct and WPS Upgrade - Design	AP/Opti	597	60087_7114	5 years	1,672	ongoing-FY18	1,672				1,672
7.27	3	Winsor Station Pipeline - Hatchery Pipeline - Design and Construction	NF	597	60077_7017 60106_7235	6 years	2,848	FY14-19	2,801	47			2,848
7.28	2	Winsor Station Pipeline - Shaft 12 Improvements - Construction	AP/Opti	597	60095_7197	3 years	8,251	FY19-21		8,251			8,251
7.29	2	Winsor Station Pipeline - Shaft 2 Improvements - Construction	AP/Opti	597	60096_7198	3 years	331	FY19-21		331			331
7.30	2	Winsor Station Pipeline - Winsor Station Rehabilitation and Improvements	AP/Opti	597	60088_7115	3 years	9,343	FY19-21		9,343			9,343
7.31	2	Winsor Station Pipeline - Power/Comm Construction	AP/Opti	597	60140_7460	1 year	534	FY15	534				534
7.32	3	Cosgrove Valve Seat Replacement - Design and Construction	AP	766	75510_7065 75509_7064	3 years	1,919	FY19-21		1,919			1,919
7.33	3	Shaft 9 Rehabilitation	AP	766	75520_7381	4 years	2,000	FY16-19	1,770	230			2,000
7.34	3	Southboro Electrical Distribution Upgrades	AP/Opti	766	75535_7425	1 year	400	FY16	400				400
		SUBTOTAL - Existing - Transmission System and Dams					**426,375**		**74,135**	**233,502**	**118,738**	**0**	**426,375**
7.35	3	Quabbin Lower Spillway Improvements	Opti	new		2 years	1,500	FY19-23		1,500			1,500
7.36	3	Earthen Dam Rehabilitation	AP	new		as needed	3,000	FY19-53		1,500		1,500	3,000
7.37	3	Masonry Dam Rehabilitation	AP	new		as needed	3,000	FY19-53		1,500		1,500	3,000
7.38	3	Cosgrove Tunnel Inspection (recurring)	AP	new		as needed	1,500	FY19, 34, 49		500		1,000	1,500
7.39	3	Oakdale Phase 2	AP	new		4 years	8,625	FY 24-29			8,625		8,625
7.40	3	Covered Storage-Nash Hill	AP	new		3 years	1,100	FY19-21		1,100			1,100
7.41	3	Covered Storage-Norumbega	AP	new		4 years	8,100	FY23-26			8,100		8,100
7.42	3	Metropolitan Tunnels-Inspection, Design & Rehabiitation	AP	new		15 years	65,000	FY30-45			15,000	50,000	65,000
		SUBTOTAL - Recommended - Transmission System and Dams					**91,825**		**0**	**6,100**	**31,725**	**54,000**	**91,825**
		SUBTOTAL - Existing and Recommended - Transmission System and Dams					**518,200**		**74,135**	**239,602**	**150,463**	**54,000**	**518,200**

8 The Metropolitan System

8.1 Chapter Summary

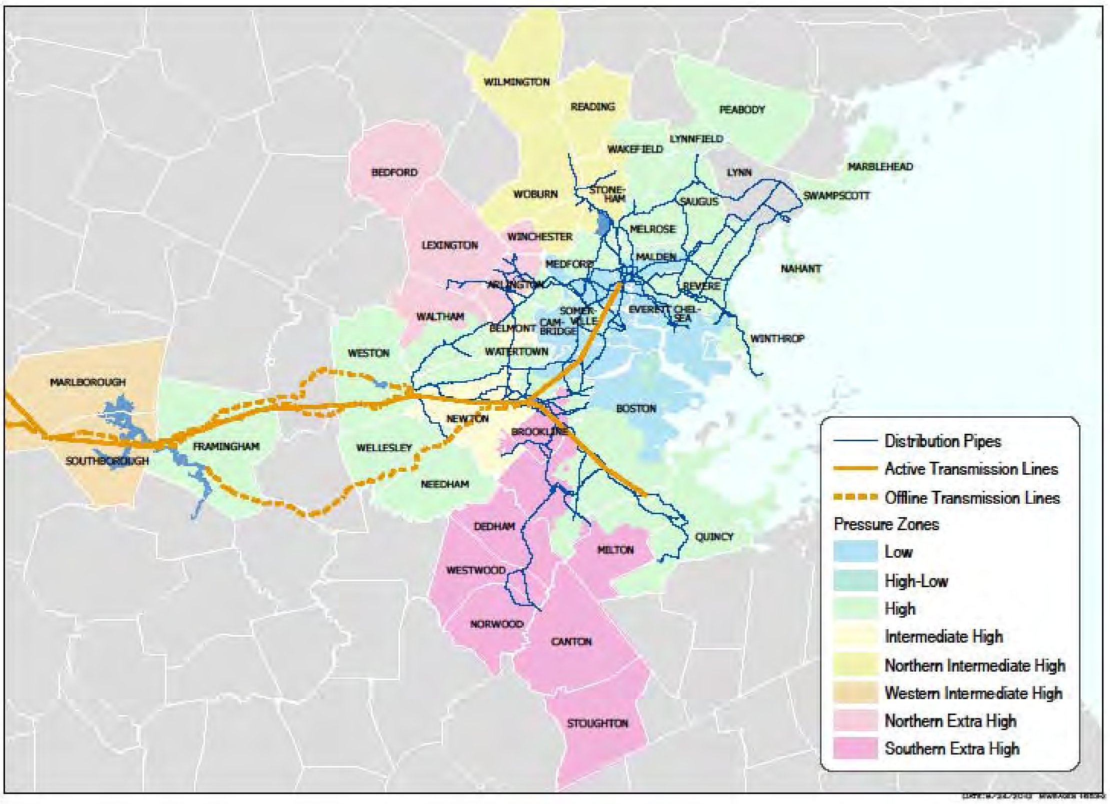
The Metropolitan Water System (also known as the Distribution system) consists of the various components shown in Figure 8-1 below:

Figure 8-1
Metropolitan System Overview



The Metropolitan Water System serves 40 communities and meets an average day demand of approximately 205 MGD in 2011. This does not include the communities of Weston and Framingham and the Western Intermediate High (Grade Line 305' BCB) of Northborough, Southborough and Marlborough. The remaining system is divided into seven (7) "pressure zone" service areas (shown in Figure 8-2) based upon the ground elevation of each zone.

Figure 8-2
Pressure Zones



The following are the service areas, and the elevations at which water is generally delivered. All elevations given are in feet, Boston City Base (BCB). The High Service as shown on the map includes both the Northern High and the Southern High pressure zones which are distinguished geographically; however, both are at an elevation of 280' BCB. For some analyses, the High System is sometimes further sub-divided to consider areas served off of Fells Covered Storage and those communities served off of the Weston Aqueduct Supply Mains (WASM).

Low Service Area (including Northern Low) (LS)	184'-200' BCB
Northern High Service Area (NHS)	280' BCB
Intermediate High Service Area (IH)	320' BCB
Northern Intermediate High Service Area (NIH)	330' BCB

Northern Extra High Service Area (NEH) –	443’ BCB
Southern High Service Area (SHS) –	280’ BCB
Southern Extra High Service Area (SEH) –	400’ BCB

The sources of water for the service areas are the tunnel shafts as shown on Figure 8-1. The tunnel shafts are supplied by the Norumbega Covered Storage Facility, which sets the hydraulic grade line for the Metropolitan system. Water from the shafts feed the surface piping system that supplies each of the pressure zones. The NLS, NHS, and SHS all flow by gravity (no pumping required). The IH, NIH, NEH, and SEH all require pumping and storage to provide service.

The “hub” of the Metropolitan Water System is the Operations Control Center (OCC), located within the Chelsea Facility. The OCC operates and monitors the entire Metropolitan system remotely. This includes hydraulic grade line (pressure) at many tunnel shafts; suction and discharge pressure, flow, and basic operation of all of the water pump stations; operating elevation and volume of the water storage tanks; pressure and flow of the supply to the customer communities; and operation of some of the key valves in the MWRA system.

From planning and design through construction and operation and maintenance of the water system, MWRA makes use of standards and manuals developed by organizations such as the American Waterworks Association (AWWA) and the AWWA Research Foundation (AwwaRF). [1]

Chapter Organization

This chapter begins with an overview of the major elements (pipelines, valves, pump stations and storage) to provide an overview of MWRA’s assets including operational philosophy, condition assessment practices, maintenance practices and performance standards and goals for those assets. This information provides a framework for the individual pressure zone sections that follow. The pressure zone sections allow for an integrated discussion of all of the distribution system assets within a pressure zone since operational flexibility may depend upon the interrelationship between these assets. A “breakdown” in any individual asset may be more or less of a problem depending upon the other assets within that pressure zone (i.e. storage may mitigate the effects of a pipeline break). Each pressure zone section identifies ongoing work within that service area and recommendations for future projects.

[1] Two documents that provide a good summary of critical requirements for the effective operation and management of drinking water distribution systems are:

- Distribution Systems Operation and Management (AWWA Standard G200-04), and
- Development of Distribution System Water Quality Optimization Plans (AwwaRF Report 91069)

These documents provide the elements for a water utility to develop and summarize Best Management Plans (BMPs) for water system management. The G200-04 standard describes the critical requirements for the effective operation and management of drinking water distribution systems. The AwwaRF report provides the processes that water utilities can use to improve distribution system operations above and beyond regulatory requirements to improve water quality and to reduce the potential for contamination.

Summary of Chapter Recommendations

Projects already in the FY14 CIP**:**

For the FY14-18 timeframe, the FY14 CIP includes the following major projects with significant spending particularly in the FY14-18 timeframes:

- $196 million for the rehabilitation and replacement of WASM 3 as part both of asset rehabilitation and optimization to make the WASM 3 line provide service to the north as part of Transmission system long-term redundancy planning. This work is expected to be ongoing between FY14-25.

- $10.4 million for design and construction for the rehabilitation of Section 36. This work is ongoing and is expected to be completed in FY17.

- $2.6 million for the rehabilitation of the Watertown section which will be completed in FY14.

- $11.6 million to construct new Section 101 to allow Waltham full service during the rehabilitation of WASM 3. This work has been somewhat delayed but is currently scheduled for construction between FY15-17.

- $9.3 million for design and construction for the rehabilitation of Section 80. This work may be changed based on the design of the southern component of long-term redundancy. Work is currently scheduled for FY17-22 but this may be altered.

- $5.6 million for the Chestnut Hill Connecting Mains Shaft 7 Building between FY22-26.

- $8.2 million for the Chestnut Hill Emergency Pump Station, Emergency Generation design and construction in FY17-21.

- $0.9 million for Northern High Service Section 27 Improvements construction in FY18-20.

- $8.3 million for design and construction of Northern High Service Sections 68 and 53A between FY15-19.

- $3.5 million for design and construction of the Shaft 9A-D extension in FY17-21.

- $8.8 million for CP-3 of the New Connecting Mains Project in FY17-22.

- $5.9 million for design and construction of the rehabilitation of Sections 59 and 60 in FY16-20.

- $3.2 million for design and construction for the replacement of Section 25 in FY16-21.

- $4.4 million for the design and construction of the Section 75 extension to link two pressure zones at same elevation and improve emergency response in the FY16-20 time period.

- $4.0 million for the design and construction of rehabilitation of Sections 34 and 45 in the Northern Extra High pressure zone in FY16-21.

- $1.5 million for installation of cathodic protection test stations during FY15-22.

- $5.3 million for remaining work for the Spot Pond Supply Mains Rehabilitation project including Section 4, bridge trusses and Section 50. This work will be done in multiple contracts during the FY14-20 time period.

- $16.4 million for rehabilitation of Southern Spines Distribution Mains Sections 20 and 58 during FY23-28

- $19.6 million for planning, design and construction of Southern Spines Distribution Mains Section 22 in FY17-25.

- $46.7 million for Northern Intermediate High Redundancy design and construction. This work is ongoing through FY19.

- $8.8 million for rehabilitation of Northern Intermediate High Sections 89 and 29.this work has to follow the completion of redundancy construction and is scheduled for FY18-23.

- $20.8 million for design and construction of Northern Intermediate High Storage in FY17-22.

- $2.2 million for Northern Intermediate High short term risk reduction measures which include community interconnections and Gillis Pump Station Improvements. Remaining work is expected to be completed in FY15.

- $16.1 million for the rehabilitation of Northern Low Section 8 in FY18-23.

- $3.9 million for the rehabilitation of Northern Low Sections 37 and 46 in FY17-20.

- $67.8 million for Southern Extra High Redundancy Phases 1 and 2. This work is proposed to be done in multiple contracts during FY14-32.

- $6.5 million for rehabilitation of Southern Extra High Sections 77 and 88. This work will follow the work above to provide initial system redundancy and is expected to be done during FY21-26.

- $11.9 million for Southern Extra High Phase 3 Storage. This work is expected to be done during FY31-37.

- $30.1 million for design/build and owner's representative work for the Spot Pond Storage Facility. This work is well underway and is expected to be fully completed by FY16.

- $25 million for the future stage of pump station rehabilitation in FY20-24.

- $10 million for rehabilitation of Northern High Section 56 in FY16-20.

- $1 million for the repairs to the Beacon Street Line in FY15.

- $1.3 million for Walnut Hill tank rehabilitation during FY16-20.

- $5 million for asset protection for elevated storage tanks. Repainting of these tanks is expected to take place between FY16-19.

- $5 million for asset protection for covered storage tanks during FY20-24.

- $1 million for planning for the rehabilitation of Sections 70, 71 and 79 in the Northern High system. This work is scheduled in advance of any design work for FY 16-17. However, it is possible that this work will be done in-house rather than through a consultant contract depending upon staff resources.

<u>Projects recommended for FY14-53:</u>

The following projects are recommended for consideration to be included in the CIP for implementation in the FY14-53 time period:

- $8.2 million for design and construction of rehabilitation for the Old Mystic Main-Section 66 in the FY24-33 time period.

- $21.4 million for the design and construction for rehabilitation of Section 57 in the FY24-33 time period.

- $16.3 million for design and construction for rehabilitation of the coastal pipelines Sections 54, 55, and 69 in the FY20-25 time period.

- $18.4 million for rehabilitation of Sections 13-18 and 48 in the Northern High system in the FY29-33 time period.

- $8 million for rehabilitation of Sections 33, 49, 49A and 50-smaller diameter unlined cast iron mains in the Northern High pressure zone in the FY29-33 time period.

- $35.7 million for the rehabilitation of Sections 70, 71 and 79 in the Northern High service area in the FY30-36 time period.

- $2.7 million for the rehabilitation of the Fisher Hill Pipeline in the FY24-29 time period.

- $8.1 million for design and construction for rehabilitation of Section 19 of the Southern Spine distribution mains in the FY24-29 time period.

- $10 million for the rehabilitation of Section 30, 39, 40 and 44 in the Southern Extra High service area in the FY34-39 time period.

- $5 million for the construction of a parallel main to Meters 55 and 68 in FY30-33.

- $0.5 million for a pipeline study to assess long-term pipeline renewal needs based on MWRA specific information. The Master Plan proposes that this work be done in FY20.

- $25 million for the next phase of pump station rehabilitation to follow the phase currently in the FY14 CIP. Work would be anticipated in the FY34-43 time period.

- $2.4 million for the rehabilitation/asset protection for the Blue Hills Covered Storage facility in FY29-31 when the facility is twenty years old.

- $9 million for Phases 10 and 11 of valve replacement in the FY24-53 time period.

Community Financial Assistance – Local Pipeline Assistance Program

MWRA began financial assistance to member water communities during FY98 and FY99 with the two-year, $30 million "pilot" program that provided grants and loans for local water distribution system rehabilitation projects. The rationale for the initial program was that funds spent on improving local water distribution systems provide greater regional water quality benefits than spending those same funds for water treatment filtration.

Building on the success of the pilot water financial assistance program, the Phase 1 - Local Pipeline Assistance Program (LPAP) was approved in FY01 to provide 10-year interest-free loans to water system communities primarily for water main replacement or cleaning and lining projects. Under the Phase 1- LPAP, $222 million in loans for local water projects were distributed from FY01 through FY13. MWRA established the Phase 2 - Local Water System Assistance Program (LWSAP) in FY11 to extend the local water loan program through FY20. This expansion of the water loan program added $210 million in interest-free loans for member water communities (including a $10 million allocation specifically for the three Chicopee Valley Aqueduct communities).

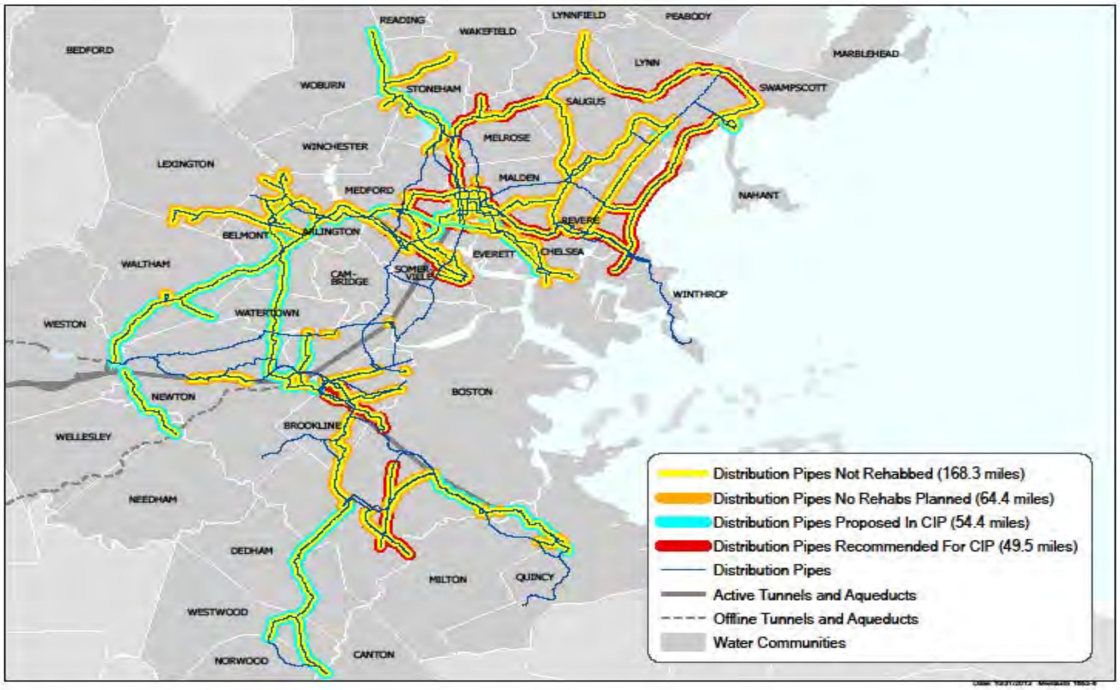
8.2 Pipelines

Since the 1993 Water Plan, MWRA has made extensive improvements in the distribution network. The 1993 Plan cited excessive leakage, hydraulic deficiencies at meters and the lack of redundancy within the distribution system as key issues. Recommendations for pipeline improvements accounted for approximately 46 of 100 projects identified in that plan. Since 1993, MWRA has constructed new pipelines where needed and has completed rehabilitation of approximately 90 miles of pipe. As shown in Figure 8-3 below, this has left a remaining 168 miles of pipeline to be rehabbed and, of that, an additional 54 miles of pipeline rehabilitation is either underway or identified in the FY14 CIP. This has left approximately 114 miles of pipeline that are not, at this time, programmed for rehabilitation. This Master Plan calls for rehabilitation of approximately 50 additional miles of pipeline. This leaves approximately 64 miles of pipeline remaining to be evaluated and scheduled over a longer time frame than is evaluated in this Master Plan.

The pipes identified in this Master Plan for future inclusion in the CIP generally reflect the continued need to clean and line older cast iron mains for the purpose of maintaining hydraulic capacity and to ensure that distribution system water quality is maintained at a high level. The major exception to this is the network of larger diameter steel mains that serve the Northern High system where it is recommended that rehabilitation be staged (planning work is in the existing CIP) and and scheduled in an orderly fashion over time prior to the maintenance needs significantly increasing.

The pipes not selected for rehabilitation at this time are primarily pipes constructed in the 1950-2000 time frame and reflect a range of pipe materials. They are also pipes without a pattern of maintenance requirements or leaks to date.

Figure 8-3
Pipeline Rehabilitation Status



As was done in 2006, as part of this master planning process staff reviewed both the industry literature on pipeline rehabilitation and replacement and at the specific experience with the MWRA system in order to determine how to assess the remaining useful life and the relative need for rehabilitation or replacement between the various pipe segments. This analysis focused on the following questions:

1. Which pipelines, if they should fail, have no redundancy to supply customers?
2. Which pipelines have exhibited the most leaks?
3. Which pipelines are located in areas which accelerate pipe deterioration?
4. Which pipelines currently have or have had material problems?
5. How can we best prioritize, using the information we have, pipeline replacement?

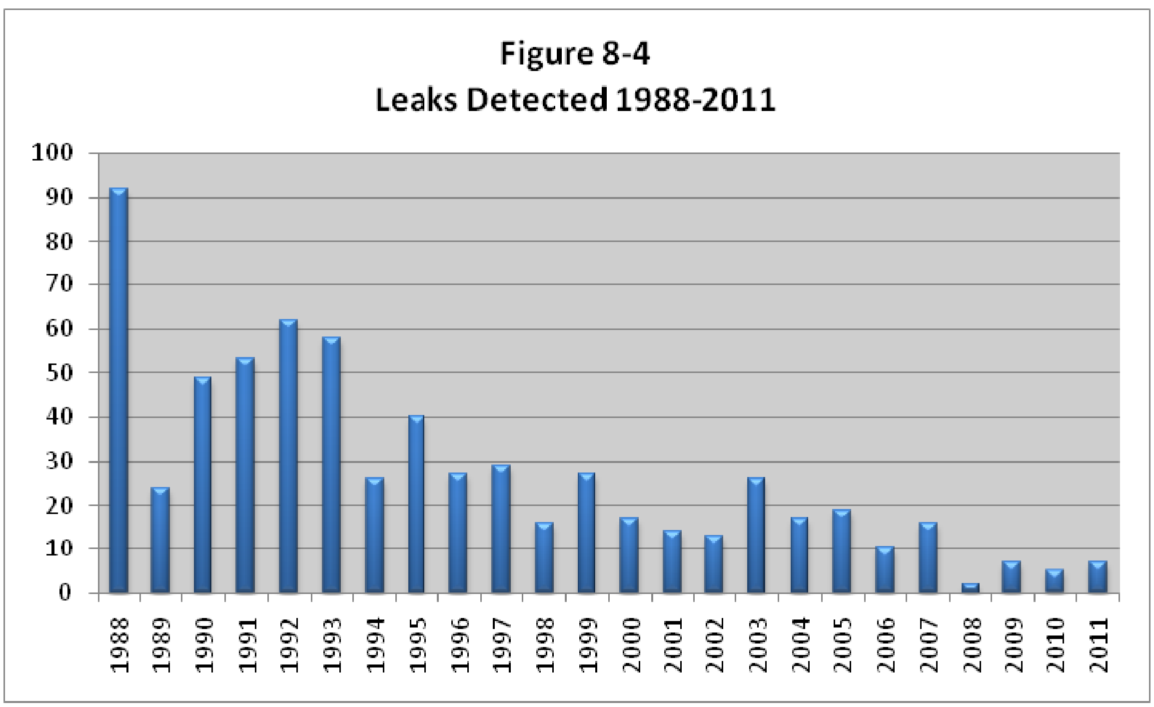
Redundancy

The goal of system redundancy has been a significant factor in water supply planning nationwide and at MWRA. Since 9/11/2001, the work completed to assess water system vulnerability has stressed the need for water suppliers to eliminate the "single points of failure" where severe loss of service could occur during a break or other emergency. This is a key element in MWRA's own goals and objectives. Pipelines without redundancy or with less than adequate redundancy were categorized based on whether the lack of redundancy presents a minor, moderate or major problem. These categories considered such factors as available storage and availability of local water supplies.

Projects to increase redundancy and/or operational flexibility focused on those areas with “major” single spine problems and are proposed in this plan. Of the three areas identified in 2006 as “major problem” areas, the Lynnfield Pipeline has been completed and concept planning and design work has begun to address single spine lines serving both the Northern Intermediate High and the Southern Extra High pressure zones. More details on proposed projects are discussed in those sections of this plan.

Pipe Structural Considerations

The questions of leaks, pipe materials and site conditions are all related. The number of recorded breaks and leaks is a factor used by many utilities as a basis for pipeline rehabilitation and replacement decisions. Leak and break data is most predictive in those large retail systems with many miles of small diameter pipe of various materials where statistical information can appropriately be generated to predict the likelihood of leaks and breaks by pipe material or age. MWRA maintains leak information in our GIS database and this information was analyzed. For the MWRA system, such data is not as good a factor to base rehabilitation decisions on except in very limited circumstances (see steel pipe discussion below). MWRA’s relatively smaller number of pipe miles (at 284), means that there may only be a few miles of pipe at most in any single age and material category which makes it harder to draw broad based conclusions about the effects of those pipeline characteristics.

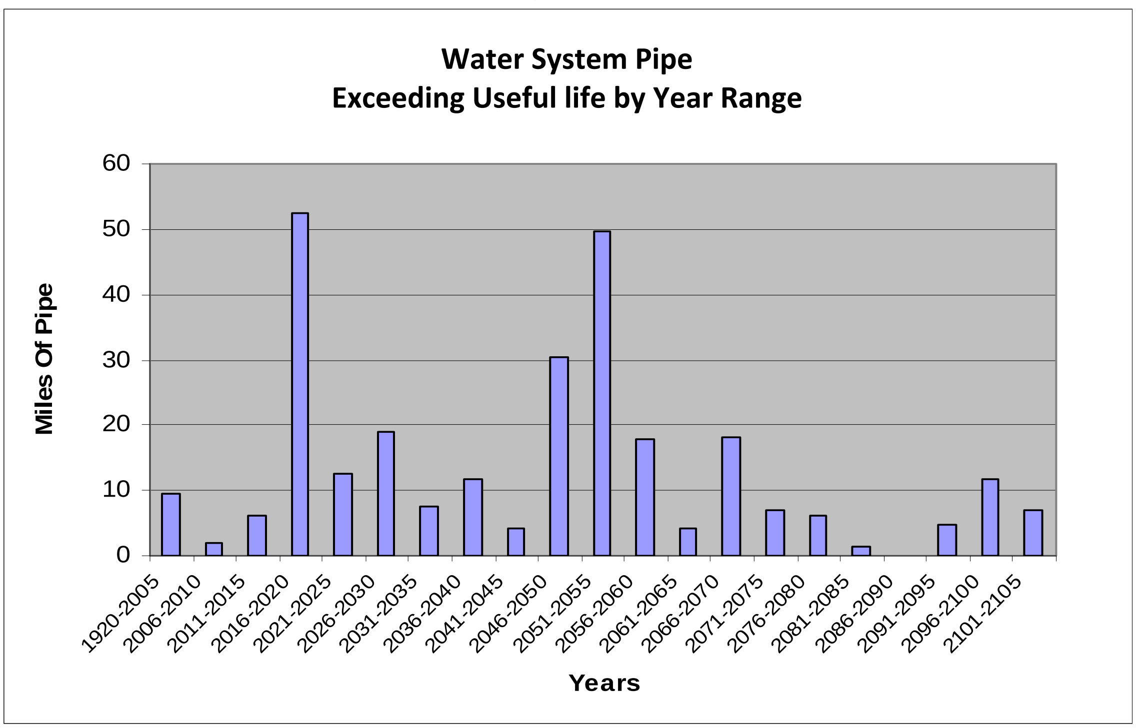


In the 30 year period prior to 1993 there were 17 pipeline sections that had between 10 and > 20 leaks in that timeframe. These pipelines were prioritized for replacement and as a result, overall leak numbers have decreased in the MWRA system and that trend has continued. Since 2006, leaks have varied between 2 and 16 per year with an average of approximately 7. MWRA has also continued aggressive leak detection. The annual goal is for staff to perform leak detection surveys of the entire MWRA system every year, and to survey the steel mains in the system twice each year. MWRA staff also assist our customer communities with special leak investigations when requested.

It is worth noting that these leaks in steel mains, while requiring repair, are usually not catastrophic failures and are often repaired while the pipes remain in service. Cast iron mains tend to have more significant circumferential or longitudinal cracking and thus are more likely to fail catastrophically.

The current literature and MWRA experience suggests that pipe age and pipe material have to be examined together to make decisions about rehabilitation or replacement. The historic rule of thumb used in the MWRA system has been that a pipe has an average useful life of 100 years with older cast iron mains lasting even longer due to their thicker pipe walls. Some literature suggests that pipes installed post WWII have an average useful life of 75 years. There can be general deterioration associated with aging pipes and many pipes are subjected to far greater surface loads and stresses than were present when the pipes were installed. However, depending upon location, soil condition and durability of construction, pipes may be quite long-lived. Although there have been many permutations of pipe manufacture in the United States, general pipe materials used in the MWRA system and their general period of installation are reflected in Figure 8-5 which

Figure 8-5



was initially shown in the 2006 Master Plan and which shows the miles of pipe in the MWRA system and the time periods when those miles of pipe will exceed (or have exceeded) their expected useful life (considering both age and pipe material). This is useful information in that it illustrates a need to systematically continue pipe rehabilitation to avoid major spikes in capital investments associated with the need to replace large amounts of deteriorated pipe simultaneously. However, this information alone is not useful in making pipe rehabilitation decisions.

MWRA experience with pipe materials since 1993 has shown that certain steel pipe sections have continued to be significant maintenance problems due to leaks associated with corrosion. Although use of appropriate pipe coatings and pipe bedding materials can mitigate the impact of the soil corrosion, these have not always been installed historically and this information is inconsistently noted in MWRA's records, limiting the predictability of such leaks. When these pipelines are located in areas of wet soils, particularly in former and present salt marsh areas, riverbanks, wetlands and floodplains, leaks appear to be more common and appear to recur more frequently once corrosion has begun to affect the pipe. There are some pipelines in areas associated with salt storage facilities that also tend to show recurring leaks. Areas with significant stray current from transportation facilities or other utilities can also be a catalyst for pipe corrosion.

Interior Pipe Condition: Hydraulics and Water Quality Considerations

In addition to the exterior condition of a pipe, another issue related to pipe materials is whether a pipe is lined or unlined. Unlined pipes (primarily older cast iron or steel) are far more susceptible to tuberculation, corrosion and pitting than more recent materials. This can impede water flow and impair water quality. Since the 1940's, pipe materials have primarily included lined steel pipes, lined ductile iron and reinforced concrete cylinder pipe. In 1993, approximately 80% of MWRA's pipe network was unlined cast iron or steel. That percentage has dropped to approximately 44% and will continue to drop as projects identified in the current CIP move forward.

Hydraulic deficiencies caused by tuberculated pipes might also be a reason to prioritize a pipe for replacement. The measure of a pipe's carrying capacity is determined by the pipe's diameter and resistance to flow, otherwise known as the pipe's "C" value.[2] C-values for new pipe are typically in the 130-140 range; C-values between 70 and 100 are indicative of pipe in poor condition and C-values below 70 are generally associated with pipes in bad condition. A C-value of 70 can deliver only about 50 percent of the amount of water that it was designed to carry. MWRA has determined C-values for all of its pipe segments and this information was also factored into the renewal analysis. In MWRA's experience, a poor C-value is not necessarily a good predictor of potential pipe failures but it is an indicator of hydraulic inefficiencies which may impact the level of service at specific locations. MWRA modeling can identify potential areas within the communities

[2] The friction coefficient of a pipe is used as the measure of flow resistance. Standard waterworks design uses the "C" value in the Hazen-Williams pipe flow formula as the parameter of resistance. Higher "C" values correlate with better conditions and lower flow resistance.

where the target hydraulic gradeline may not be met under max day conditions. Many of these locations reflect development on hills at a grade higher than that served by the MWRA's pressure zone so the most common means of addressing such deficiencies is community construction of local booster pumping stations.

Besides being hydraulically inefficient, tuberculated cast iron pipe may be a source of water quality problems. The accumulation of metallic salts and rust (tubercules) on interior pipe surfaces can lead to water quality complaints related to discolored water which, in some instances, can result in staining of fixtures or laundry items. In addition, the presence of tubercules may also lead to opportunities for bacterial growth along the pipe walls. Industry practices suggest that it is preferable to replace such pipe from the inner core of the system outward. Most water quality complaints relative to "colored" water are related to work in community systems where flow is disrupted or changes direction. This tends to break off or scour rust from the pipe interior and transport to the service lines. However, concerns about potential bacterial growth are very relevant to both the MWRA and community systems and as noted in Chapter 5, future regulatory actions will likely address the need to maintain water quality within the distribution system.

Methods of Pipeline Rehabilitation

Pipelines can be renewed, rehabilitated or replaced depending upon the location and circumstances. Each of the strategies below yields different benefits in terms of extending the life of the asset.

Cleaning & Lining: This is a process which cleans and resurfaces the interior of an old pipe to make it comparable to a new pipe's interior. The old pipe must be structurally sound and expected to remain intact for another 50 years for a pipe to be a candidate for this technology. The pipes are cleaned, lined with cement mortar and valves or other appurtenant structures are replaced. This can be approximately 40% less expensive than the cost of pipeline replacement and based, on industry literature can extend the life of the old pipe by up to fifty years or longer. Water quality benefits may also be gained by the cleaning and lining of cast iron pipe.

"Sliplining": This technology involves inserting a smaller diameter pipe within the existing pipe and either expanding the insert or filling the annular space with grout. There is an associated loss of hydraulic capacity which must be closely reviewed to determine if such loss is acceptable. This is less expensive than conventional replacement due to the use of smaller pie. It is most often considered when the loss of capacity is not problematic and where conventional construction methodologies are extremely difficult due to access or construction impacts.

Replacement: This technology entails the removal of the pipe segment and the replacement of it with a new pipe segment generally of the same size (depending upon capacity needs). Typically, this is used where a pipe is structurally in poorer condition and ongoing maintenance of the existing pipe would not be cost-effective or would pose risks to service.

Parallel Piping: This methodology entails the installation of a new pipeline in parallel with the existing pipeline. The old pipe may not remain in service depending upon the specific conditions and needs in that service area. This approach can be preferred where additional service objectives must be met by the project, where pipe replacement is excessively costly or disruptive or where additional capacity or redundancy may be needed.

MWRA has used all of these technologies over time depending upon the site specific circumstances. Based on work done to date, staff generally assumes for the purposes of preliminary cost estimates that two-thirds of the pipeline length can be rehabilitated through cleaning and lining and that one-third of the pipeline will require replacement. Actual determinations are made during design for most projects. Sliplining may also be evaluated as an alternative during the design process depending upon site specific conditions. However, for some projects, initial recommendations specifically call for parallel piping. This is generally because the pressure zone evaluations have identified a need for pipeline redundancy or for additional capacity to serve a specific area. Selection of pipe materials is also dependent upon review of the project by engineering, operations and construction staff and includes consideration of soils, location and specific pipe design characteristics (for example, long straight sections versus many bends and turns). In addition, for those areas where record drawings are not available or are inaccurate, there may be a need to change or fabricate piping connections in the field, resulting in materials such as steel, which are more suitable for such modifications. Consultation with local officials provides an opportunity for their input into project design.

Pipeline Prioritization

A number of factors have been used be MWRA to make the recommendations contained in the Master Plan. Redundancy projects, particularly for the NIH and SEH systems ranked very highly towards maintaining reliable service within the Metropolitan system. Additional projects that remedy other system vulnerabilities and/or increase operational flexibility during emergencies are also highly ranked.

The continued systematic removal or lining of unlined cast iron and steel mains is also recommended. Remaining unlined cast iron, although it may have the greatest longevity of pipe materials, can create hydraulic inefficiencies and water quality problems. It is expected that future distribution system regulatory requirements will also focus on the need to remove unlined pipes. In addition, when cast iron pipes fail, they often fail catastrophically, resulting in damage to homes, businesses and roadways. For steel pipes, recent literature suggests a life expectancy of approximately 75 years and MWRA experience suggests that once corrosion begins, steel pipes begin to experience leaks and leak frequency begins to accelerate over time. Although these can often be fixed “live”, (with the line in service), depending upon their location, these lines create a greater and greater drain on maintenance staffs.

Recommended Actions and Capital Improvements-Pipelines

The pressure zone sections of this plan identify the specific pipe sections recommended for rehabilitation and the proposed cost and schedule. However Figures 8-6 and 8-7 below provide an overview of the recommended cast iron and steel pipe rehabilitation work that is proposed.

Figure 8-6
Cast Iron Mains Proposed for Rehabilitation or Replacement

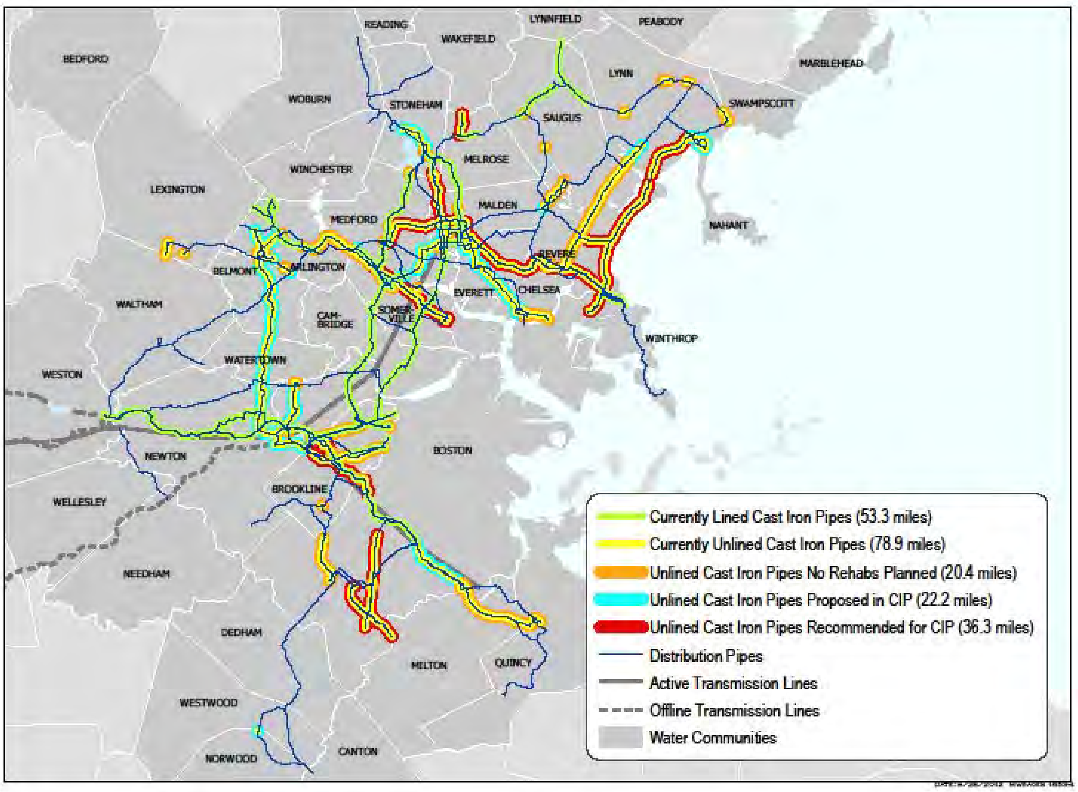
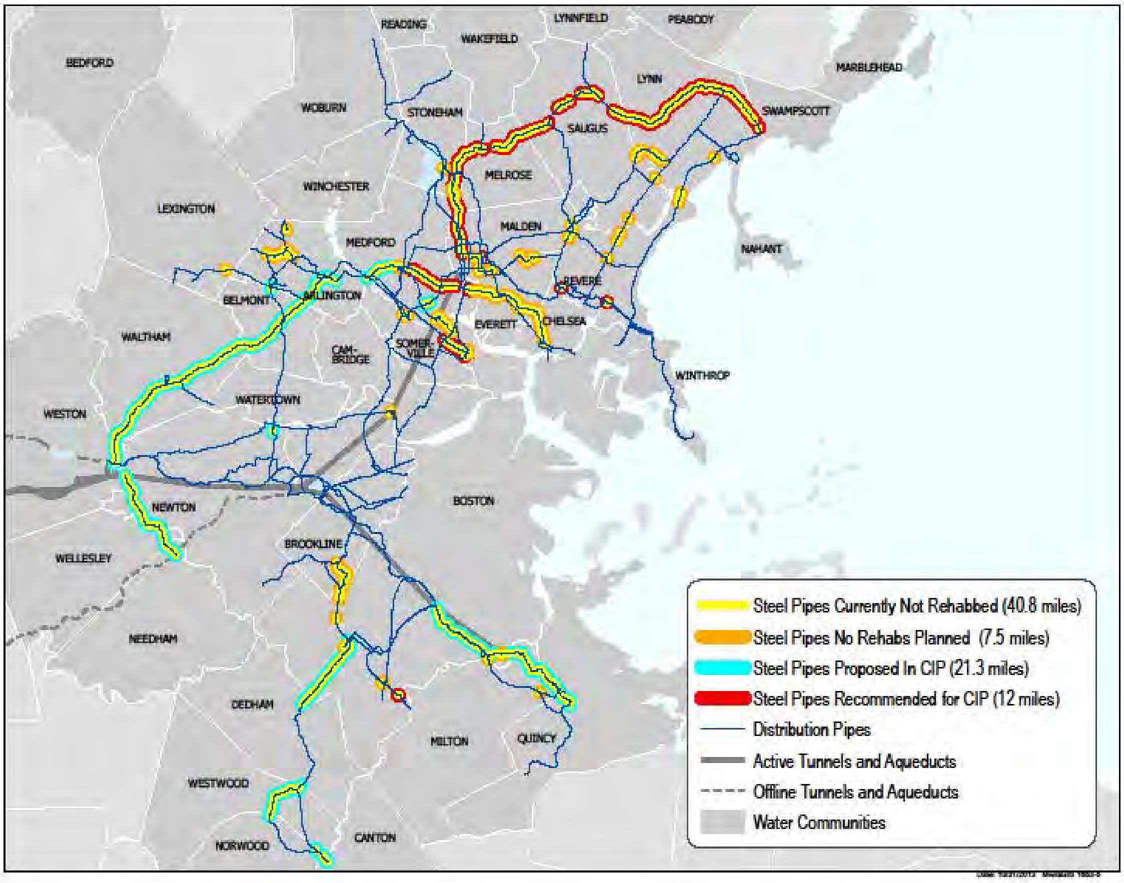


Figure 8-7
Steel Mains Proposed for Rehabilitation or Replacement



8.3 Valves

There are over 4900 valves in the MWRA Metropolitan water system. Valves provide the means to control the flow of water in the pipes, and their operability is critical. Valves provide the means to isolate leaking or broken water mains, control the flow of water in redundant piping systems, reduce pressure depending upon service area needs, and to allow pipes to be shut down (isolated) and drained so that new or rehabilitated water mains can be connected to the existing water system.

Types of Valves

The following are the types and numbers of each of the valves that are currently in the Metropolitan water system.

Table 8-1

Valve Type	#	*What it does*
Main Line	1308	Control water flow in the distribution pipelines and isolate flow in and around pump stations, tanks and reservoirs.
Meter	604	Control water flow to the community meters.
Cross Over	92	Control water flow in the distribution system between pipelines of similar pressure (within pressure zones).
Division Gate	20	Control water flow in the distribution system between pipelines of different pressure (normally closed).
Emergency Connection	98	Allow water to flow from the MWRA system to the community system without metering (normally closed).
Control-Check Valves	113	Allow flow in only one direction and are normally installed immediately up or downstream of a community meter. Contains water in the community system in event of a major MWRA break.
Control-Pressure Reducing	48	Reduce the Norumbega gradient (270' BCB) to the Northern Low gradient (185') to prevent over pressurization.
Blow Off	1206	Allow water to be released from the distribution pipelines to drain lines, provide for flushing or for disinfection preparation.
Air Release	1336	Allow air to enter or leave distribution pipelines during filling or draining of lines.
Bypass	88	Small diameter gate valves installed on piping around newer, large diameter butterfly valves

Valves of particular importance include the pressure reducing valves (PRV) that reduce the hydraulic grade line from Norumbega Covered Storage Tank (NCST) to the Northern Low Service (NLS) pressure zone. PRV are located at most of the tunnel shafts, and at many meter connections to customer communities. The OCC monitors the performance of the PRV to confirm that they are operating within the required parameters. Blow off valves are notable in that they are used to dewater the MWRA pipelines for a variety of reasons and were originally designed to flow into drainage lines, sewer lines, or direct discharges to surface water bodies (primarily small streams). The Massachusetts Department of Environmental Protection (DEP) determined that the direct connections constituted a cross connection condition, and need to be severed in order to eliminate the potential health hazard. In addition, discussions are ongoing with DEP relative to whether air release valves may pose a potential possibility of cross connection and the appropriate means to address such hazards. It is likely that some portion of future valve replacement funds will be necessary to address this issue.

<u>Valve Database and Performance Standards for Valves</u>

All maintenance done at the MWRA is managed through the use of a computerized maintenance management system (CMMS). The specific software package used is MAXIMO and all water system maintenance work is captured on work orders within MAXIMO. This database allows for reports to be run on demand to determine the current valve operability for any of the valve types in our system. The database contains all of the pertinent valve information, such as age, material, manufacturer, number of turns to open or close, and maintenance history. Valve operability is reported on a monthly basis, as a part of our overall maintenance management reporting.

The MWRA has established criteria with associated codes to define the operability of the valves in our system. The following are the codes and their definitions as used to define valve operability.

Code	Definition	Meaning
OE	Operable/excellent	Full number of turns achieved
OA	Operable/adequate	Enough turns achievable for an adequate shut down in an emergency
PI to	Partially Operable	Partial closure achievable but inadequate shut down in an emergency
FO	Frozen open	
FC	Frozen closed	
FU	Frozen in unknown position	
AB	Abandoned	
BA	Broken Air Valve	Air valve inoperable, do not operate
RE	Removed	Valve removed from the system
SP	Special Status	Position and operability never checked “Do Not Touch”
UN	Unknown position	Presently unknown, due to inaccessibility & operability
Not Visit	Not yet visited	Valve has not been visited by crew

The MWRA considers the valves in the OE and OA categories as those that are operable. All others are considered inoperable, except for those that are abandoned or removed.

The physical condition of most of the valves in the MWRA system is good to excellent which is a significant improvement over the situation in 1993 where the Plan said “Operational experience with mainline valves indicate that many valves are inoperable or only partially operable due to a general lack of maintenance for many decades” . It is

difficult to make a gross assessment of valve condition, however, and individual reporting, using valve operability statistics provides a much better method of valve conditions. Capital construction projects, in-house valve replacement, and valve maintenance programs (discussed below) have made a great improvement in the overall condition of the valves.

Table 8-2
Valve Operability-2012

Valve Type	Total	Operability
Main Line	1308	86%
Air Release	1336	90%
Blow Off	1206	90%
Control-PRV	48	92%
Total All Others	979	N/A

Valve Maintenance Program

Pipeline and Valve crews are dedicated to water system maintenance. Pipeline crews replace broken or inoperable valves, repair leaks, retrofit blow off valves, and perform a variety of other tasks. The valve maintenance program includes the goal setting and tracking stressed in the standards set by the AWWA.[3] The goal is to exercise all main line valves once every two years. However, some valves cannot be exercised as it would cause a loss of supply in the system. This is the case when a redundant line is out of service due to a construction project, leak repair, or some other maintenance activity. Closing of the valves on the active line

[3] Valve exercise program. The utility shall have a valve exercising program. This program shall include at least the elements:

a. A goal for the number of transmission valves to be exercised annually based upon the percentage of the total valves in the system.
b. A goal for the number of distribution valves to be exercised annually.
c. Measures to verify that the goals are met and written procedures for action if the goals are not attained.
d. Critical valves in the distribution system shall be identified for exercising on a regular basis. Potential quality and isolation concerns shall be recognized. The program shall track the annual results and set goals to reduce the percent of inoperable valves.

The AWWA also publishes a series of Manual of Water Supply Practices. One of these manuals is M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance. This manual provides the following for guidance in the planning of a maintenance schedule for valve exercising:

- Inspections should be made of each valve on a regularly scheduled basis (annually if possible) and at more frequent intervals for valves with a 16" diameter and larger.
- All gate valves should be cycled from full open to full close and back to open at least once every two years.

would cause a disruption in service. Valve exercising can drop to as low as 10% of the work load in the summer months, as the majority of the time is spent on construction support and the other activities.

Work to date

There have been dramatic improvements in system performance in the last 15 to 20 years, due to the success of the combined program. Since the completion of the 2006 Master Plan, Phases 6 and 7 of the ongoing Valve program have been completed at a construction cost of approximately $4.4 million. Phase 6 included 4 blow-off valve retrofits, 8 main line valve replacements and 9 globe valves for tank isolation. one check valve and rehabilitation of one meter. Phases 8 and 9 of the valve program are now in the CIP. Design of the 2 phases is expected to cost $1.2 million and begin in January of 2016 and construction for the two phases is expected to begin in January of 2018 at an approximate cost of $5.1 million. The FY14 CIP also reflects the equipment purchases necessary for these phases with approximately $3 million being spent in FY14-18 and beyond. Valve replacement that occurs through the pipeline rehabilitation program must also remain in place. Over 200 valves have been replaced by MWRA staff as a part of the program.

Recommended Actions and Capital Improvements-Valves

- Two additional phases of valve replacement (Phases 10 and 11) are recommended at a cost of $9 million with a start date of FY 24. In order to continue to increase the percentage of operable valves and to address valves that fail during the next 40 year period, work will need to continue using both the current CIP project and in-house design services. In addition, it is expected to take additional time to complete the blow off valve retrofit program. The mix of in-house and CIP work on all phases of the MWRA valves has been the key to operational success of the system.

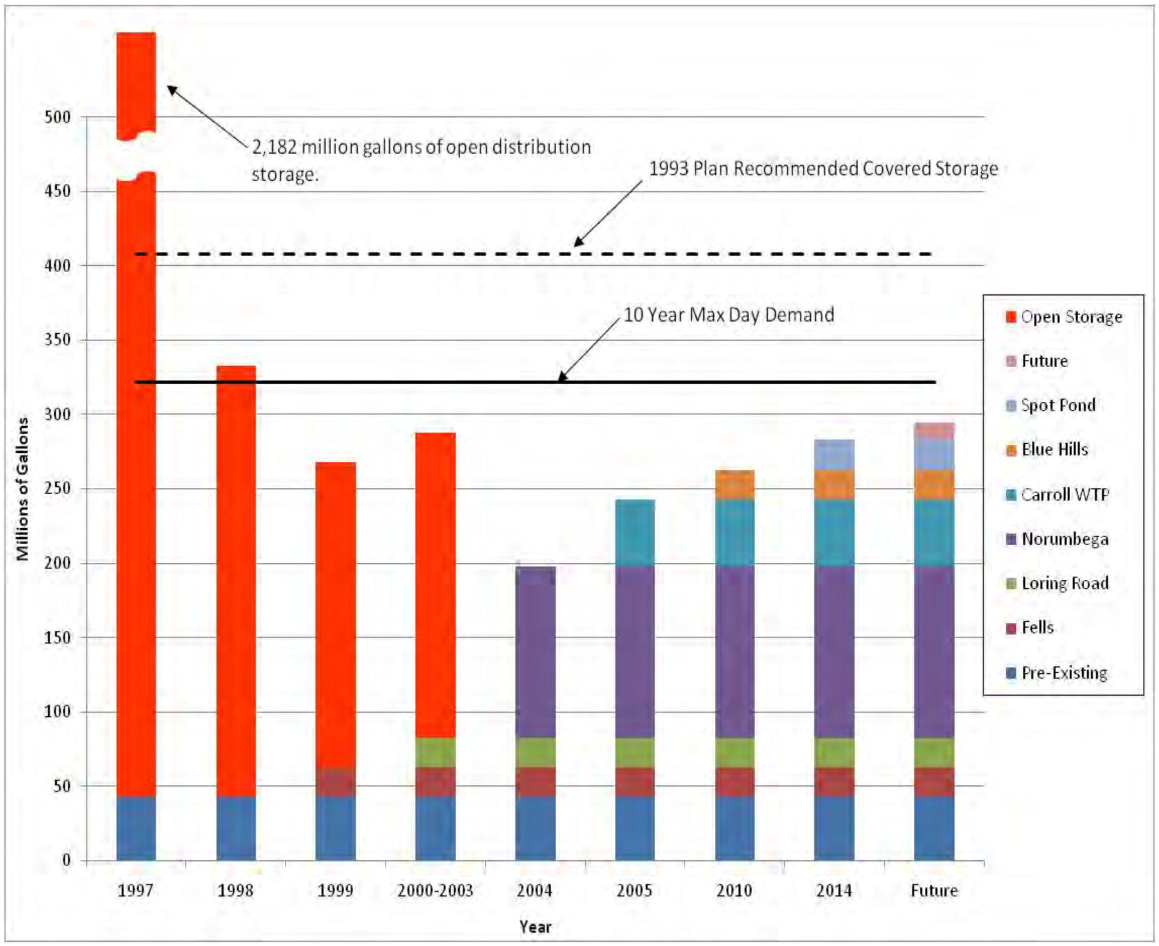
- Staff should also continue to monitor the maintenance needs for the butterfly valves that have replaced gate valves in various parts of the system. Gate valves have routinely had an expected life in the MWRA system of 50-75 years and there is some concern that the butterfly valves may not be as resilient and more prone to breakage and misalignment. For the next master plan update, review this information and complete a revised life cycle cost analysis if appropriate.

8.4 Storage

The majority of the water (81%) delivered in the Metropolitan area is done by means of gravity. The remaining 19% is delivered through the use of pumping stations and the 11 water storage tanks. In 1993, MWRA had approximately 2,182 MG of open distribution storage in Eastern Massachusetts. MWRA had initiated efforts to comply with the regulatory requirements to eliminate uncovered storage. Although work was in the early stages, MWRA accepted that the requirement would greatly reduce the storage volume available. Based on generally accepted standards, MWRA's planning assumptions were based on the need to provide a storage quantity equal to a max day demand for the system. The 1993 Master Plan enumerated the projects identified by the 1993 *Water Distribution System Storage Study* and noted that by 2017 covered storage within the distribution system should approach 345 MG (including Nash Hill in the Chicopee Valley Aqueduct (CVA) system but not including planned storage of 50 to 100 MG at the proposed water treatment plant). This would get MWRA close to the 1993 conservatively projected goal of having storage for a max day demand of 460 MG.

As shown in Figure 8-9, since 1993 major uncovered reservoirs at Norumbega, Weston, and Spot Pond have been disconnected from the system. However, significant covered storage has become operational as Fells, Loring Road, Norumbega, the Carroll Water Treatment Plant and Blue Hills have come on line. In addition, twenty million gallons of storage for the Low system is currently under construction near Spot Pond (the future Spot Pond Covered Storage Facility) and this is expected to be completed in 2014. Three facilities recommended in 1993 have not been constructed. Additional storage has not been constructed for the Northern Intermediate High service area, the Southern Extra High service area, and in the Lynn/Saugus area (Northern High). The 1993 report also noted that additional long-term storage could be constructed in the Fells to supplement both the Northern High and the Low service areas. MWRA now has 263 MG of available storage in the Metropolitan system (excludes Nash Hill in the CVA system). The Spot Pond facility will increase this to 283 million. MWRA also anticipates the future addition of approximately 12 MG of storage within the Northern Intermediate High and Southern Extra High systems for a longer-term total of 295 million gallons. The ten year average max day demand shown on the chart is 322 million gallons so anticipated storage volumes will not quite reach that level.

Figure 8-9



<u>Recommendations for Additional Storage</u>

No additional storage needs are currently proposed beyond the projects previously identified to increase storage in both the Northern Intermediate High and Southern Extra High service areas. These projects should proceed as agreements relative to storage tank siting can be resolved.

Purpose of Storage

Distribution storage tanks serve two important functions in a water system: they provide equalization flows to dampen the effects of daily flow variations and they provide emergency storage in the event of a short-term supply disruption[4]. Thus, it is necessary

[4] **Equalization storage** is the amount of water necessary to supply peak water usage at times when the demand exceeds the system's delivery capacity. The availability of sufficient equalization storage keeps the elevation of stored water within an acceptable range, thereby preventing excessive reductions in pressure. During times of maximum demand, water flows from the distribution storage facility to the consumers. When demand drops off, the flow refills the reservoir. The volume of equalization storage

for a distribution storage tank to have an elevation high enough to provide adequate pressure throughout the system served.

However, the MWRA system may present some flexibility in terms of emergency storage. Although, ideally, most system emergencies should be handled transparently to the communities and end consumers with system operations automatically or unobtrusively shifting to the use of emergency storage, MWRA has not lost the ability to use the large uncovered reservoirs in the event of a significant system problem. This type of shift would not be transparent and would be accompanied by water restrictions, boil orders etc. but a level of service could be maintained. The ability to use the uncovered reservoirs in an extreme emergency can be considered in determining the right amount of new covered storage for the MWRA system.

Locating Storage

The ideal location for distribution storage is affected by many factors but should reflect where demands are located within the pressure zone. This set-up results in minimal head losses and pressure fluctuations, since, on average, the water travels the shortest distance from its storage location to the consumer. Distribution storage should be relatively proportional to water demand in each of the service areas. The original open reservoirs at Norumbega, Fells Reservoir and Blue Hill Reservoirs were laid out in such a way to meet this objective and these locations are now the site of the key covered storage reservoirs (including the future Blue Hills Covered Storage facility). The remaining smaller covered storage, which receive pumped water from the MWRA system, are located on hilltops in the areas served.

Storage Facility Condition Assessment

The nine active storage and two stand-by facilities in the Metropolitan system range in actual age from 4 to 98 years old (excluding Norumbega which is west of the Metropolitan system). Spot Pond Covered Storage is expected to come on line in 2014. Generally, prestressed storage structures have expected lives of 50 years while cast-in-

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required for an area is a function of the magnitude and variability of water usage and the capacity of the water delivery system.

Emergency storage is the quantity of storage required to maintain water service in the event of an interruption in supply due to circumstances such as a pipeline break or a mechanical malfunction. The amount of emergency storage required depends upon the magnitude of water usage and the anticipated response times for emergency repair operations. It is common practice to design water systems to have enough overall distribution storage to meet at least one day's maximum demand. To appropriately serve a large region with variable land elevations, individual distribution storage facilities must be appropriately sized and located relative to the needs of each service area.

The sum of equalization and emergency storage volumes equals the total useable storage. A relatively small volume of water is also necessary to provide a buffer depth at the bottom of a storage facility to maintain the water quality of the water leaving the tank. This amount is called reserve volume.

place concrete structures have expected lives of approximately 100 years. For the purpose of the asset value analyses done in 2004, MWRA assumed that overall, MWRA's storage facilities had an average useful life of 80 years. Internal piping and appurtenant structures are expected to last approximately 50 years. In addition, for those facilities significantly rehabbed, the 2004 analyses reset the clock at 80 years of useful life. The age, material and operating condition of each of MWRA's storage facilities is found on the table below.

Table 8-3

Storage Facility	Year Built	Year Rehabbed	Years to Next Rehab*
Arlington Covered Reservoir (active)	1937		4
Arlington Heights Standpipe (standby)	1922	1999	66
Bear Hill Tank (active)	1986		53
Bellevue Standpipe #1 (standby)	1915	1999	66
Bellevue Standpipe #2 (active)	1955	2000	67
Deer Island Tank (active)	1994		61
Turkey Hill Tank (active)	1945	2000	67
Walnut Hill Tank (active)	1961	1999	66
Fells Covered Storage (active)	1999		66
Loring Road Covered Storage (active)	2000		67
Blue Hills Covered Storage (active)	2010		77

*Years to Next Rehab-Remaining Useful Life from MWRA asset replacement analysis; however, interim asset protection measures will be required.

Routine maintenance practices do need to be applied to storage facilities to ensure that structural features are secure. Catastrophic failure is not generally a concern but gradual problems can include cracks in side walls, internal and/or external ice damage, loose or fractured welds, broken control valves or other appurtenant piping, damaged overflow weirs and malfunctioning instrumentation. However, the "failure mechanism" would likely be rusting, followed by weeping, followed by leaking.

AWWA recommends that finished water storage facilities undergo an in-depth inspection every 3 to 5 years. The MWRA started an inspection program in 1999. Five water tanks were cleaned and painted in 1999-2000 and all others were inspected in 2000-2001 with two requiring cleaning. MWRA has continued a five-year inspection cycle and as a result, based on some evidence of corrosion, a full structural analysis of the Walnut Hill tank has been scheduled in the CIP for the FY 16-20 time period at a cost of approximately 1.3 million with the level of work dependent upon the results of the structural analysis. In addition, the FY14 CIP also contains $5 million for the next round of elevated storage tank painting in the FY16-19 time period. This project is anticipated to include the two Bellevue tanks, Park Circle, Turkey Hill and Walnut Hill. In addition, though the useful life is predicted to be 80 years as noted above, for the covered storage facilities, it is recommended that valves, sluice gates and pipe be inspected and replaced as necessary at approximate 20 year intervals. The FY14 CIP contains $5 million for this work at Fells and at Loring Road to be done in the FY 20-24 time period. Although the Arlington Covered Reservoir (constructed in 1937) would appear to need rehabilitation in the FY14-23 time frame, it has been inspected and been determined to be in good condition.

Recommended Storage Projects:

- It is recommended that $2.4 million be added to a future CIP for evaluation and rehabilitation of mechanical and other equipment as necessary for the Blue Hills facility in the FY29-31 time period. Similar maintenance work will be identified in the next Master Planning cycle for the Spot Pond Covered Storage facility once it has come on line.

Water Storage Tank Operation and Maintenance

The operation and maintenance of water storage tanks requires that attention be paid to tank level monitoring, operating ranges, turnover rates, mixing process, and water quality. Maintenance has to consider activities required on a routine, annual, and detailed inspections basis. Security issues, including fencing, inspection frequency, and access have become a significant issue for both MWRA and for the community-owned storage facilities.

The OCC monitors the water storage tanks, pump stations, pressure reducing valves, community meters, and tunnel shafts. The individual water storage tanks are controlled using programmable logic controllers (PLCs) at the pump station that is the tank's source of water. Normal operation is managed by the OCC remotely. In the event of a loss of communications from the OCC, the PLC is capable of operating the pumps and the tank levels on a local/remote basis. All of the tanks have high and low level alarms to alert the operator at the OCC if there is a problem.

Maintaining Water Quality

Maintaining the best quality of water possible is accomplished by monitoring the turnover rates, mixing process, and water quality of each of the water storage tanks. This provides for the lowest water age, and in turn, the highest water quality.[5] The turnover rates calculated for the MWRA tanks were determined to be between 1.3 and 2.4 days

[5] The AWWA Research Foundation (AwwaRF) published a report titled "Maintaining Water Quality in Finished Water Storage Facilities" (AwwaRF report 90763, 1999), The study recommends water in storage tanks should be turned over an average of every 2.5 days to minimize water age and maximize water quality. A 2.5 day turnover rate translates to a 40% daily turnover in tank volume.

(which equate to daily rates of 40% to 77%). Another element to promote the optimum water quality in storage tanks is through the mixing process. This can also help to minimize water age, and to minimize stagnant zones in the tank. The mixing of the water in the tank is encouraged by a more aggressive or turbulent flow into the tank. Confirmation of water age and water quality is through weekly water quality samples taken at each water storage tank. MWRA samples each tank every week to confirm water quality[6]. If water quality sampling and testing continue to show a drop in chlorine residual, despite operational changes, then more drastic measures, such as draining the tank, may be required.

8.5 Pump Stations

Since 1993, the initial work to rehabilitate the Spot Pond (now the James L. Gillis P.S.), Commonwealth Avenue, Lexington Street and Newton Street pump stations has been completed, as well as work to construct the Chestnut Hill emergency pump station. Since the 2006 Master Plan, the remaining five pump stations at Brattle Court, Reservoir Road, Hyde Park, Belmont and Spring Street have also been rehabilitated. Work included installation of new mechanical, electrical, instrumentation and security systems with building and site refurbishment. A fast track contract completed in 2001, installed SCADA systems at each station and all stations are now remotely operated. The Dudley Road Pump Station in Newton was rehabilitated in 2006 by in-house staff. Please also see Pressure Zone discussion.

Based on a recommendation in the 2006 Master Plan, the FY14 CIP contains an additional $25 million for the next stage of pump station rehabilitation (for those stations initially upgraded). This work is proposed in the FY20-24 time frame.

<u>Recommended Projects</u>

- Staff recommends that an additional $25 million be added to the CIP in the FY34-43 time period for the next cycle of pump station rehabilitation for those stations completed in 2010. This would include replacement of instrumentation, electrical and mechanical systems at the pump stations.

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[6] Field Operations coordinates with the OCC staff so that the tanks are at the appropriate elevations to allow for a sample to be taken. Crews radio the OCC while driving to each tank, to confirm that water is leaving the tank. This way the sample is sure to be from the tank, and not inbound system water. If the tank is filling, the OCC notifies the crew to wait anywhere from 15 to 30 minutes to make sure that the pumps are disabled, and water is flowing out of the tanks. The crew performs a field chlorine residual test, and radios the results to the OCC. Sample bottles are taken to the lab for bacteria testing. Results are published in the weekly and monthly operations reports. The sample results are plotted and are monitored by Metropolitan Operations staff, and Quality Assurance staff. A threshold level of 1.0 mg/l is used to review water quality, and determine if operational changes should be made, such as increasing the operating range to move more water in the tank. The specifics of each tank is considered, such as the existence of separate inlet and outlet piping, configuration, and volume and the disinfection methods used must also be considered. The use of chloramines suggests that testing for ammonia and nitrification needs to be done in the warmer months.

Table 8-4
Pump Station Overview

Pumping Station	Pressure Zone Serviced	Capacity (mgd)	Year Built	Year Rehabbed
Gillis, Stoneham	Northern High Northern Int. High	35	1900	1998
Brattle Court, Arlington	Northern Extra High	12	1907	2010
Spring Street, Arlington	Northern Extra High	20	1958	2010
Lexington Street, Waltham	Northern Extra High	2	1949	1998
Belmont	Intermediate High	6	1937	2010
Commonwealth Ave., Newton	Southern Extra High	20	1952	2000
Hyde Park Ave., Hyde Park	Southern Extra High	8	1912	2010
Reservoir Road, Brookline	Southern Extra High	5	1936	2010
Newton Street, Brookline	Southern Extra High	19	1954	1998
Dudley Road, Newton	Southern Extra High	1	1954	2006
Chestnut Hill Emergency P.S.*	Southern High	90*	2001	

* The Chestnut Hill Emergency Pump Station was constructed to supply the Southern High and Southern Extra High in an emergency by taking water from the Sudbury Aqueduct via the Chestnut Hill Reservoir or by taking water from the Low Pressure system. The 90 mgd capacity reflects the station taking non-potable water from the Chestnut Hill Reservoir.

Broken down by component, pump stations have an average useful life of 10-50 years. Computer control systems, generally used as a part of the Supervisory Control and Data Acquisition (SCADA) systems have a useful life of between 10 and 15 years. This is due to the nature of the computer industry, and the pace at which technology changes. Routine condition assessment of pump station equipment has been initiated in order to identify any equipment or instrumentation issues.

Please see Table 9-1 in Chapter 9 for recommended SCADA equipment replacements and upgrades.

Maintenance Practices

There are a variety of maintenance activities that are performed at the pump stations. Theses preventative maintenance (PM) tasks are performed on a monthly, quarterly, semi-annual, and annual schedule, depending upon the type of equipment. The following are examples of the equipment that are maintained at the pump stations:

- Emergency Generators
- Motors
- Pumps
- Motor Control Centers
- Surge Control Valves

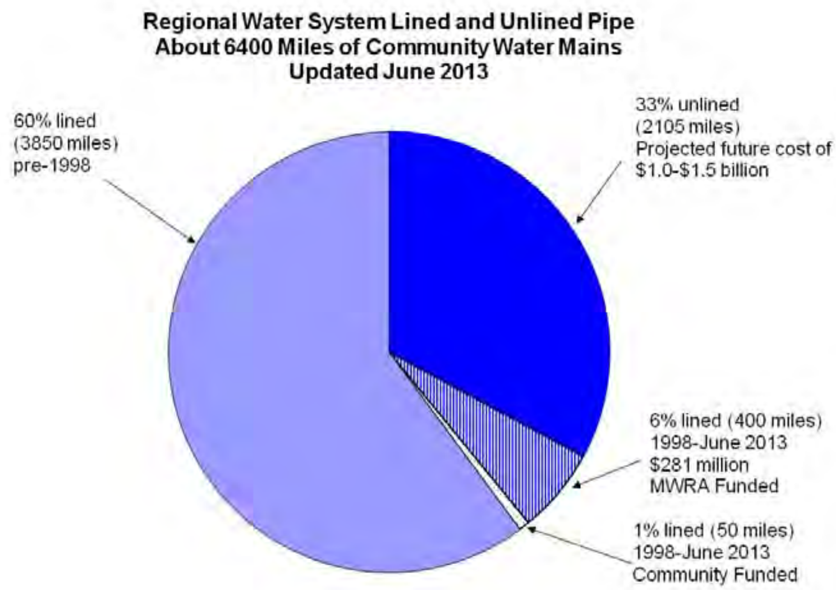
Although recent and ongoing rehabilitation projects have addressed the major capital needs of these facilities, the useful life of certain components including equipment such as pumps and instrumentation are generally within the 20-25 year time range and equipment replacement is expected to be necessary within the Master Planning period. In addition, Field Operations continually evaluates opportunities for facility optimization. As part of this, VFDs have been installed in a number of pump stations and this will continue as part of the remaining rehabilitation work. For this reason additional VFDs are also likely to be installed in Gillis Pump Station.

8.6 Local Pipeline and Water System Assistance Program

MWRA's goal in providing financial assistance to member communities is to improve local water systems to help maintain high quality water as it passes from MWRA's facilities through local pipelines to customers' taps. Continued improvement of local water systems is a critical element of MWRA's Integrated Water Supply Improvement Program and was a component of the Board's October 1998 treatment technology decision for the John J. Carroll Water Treatment Plant. Older water mains, particularly those constructed of unlined cast-iron pipe, need to be replaced or cleaned and lined to prevent tuberculation (rust build-up), loss of disinfectant residual, and potential bacteria growth.

Unlined tuberculated water mains

Through the end of FY13 (June 2013), approximately 33 percent of locally-owned distribution systems remain unlined, representing a regional need of approximately $1.0–1.5 billion for future water main rehabilitation, as depicted in the pie chart below.



MWRA began financial assistance to member water communities during FY98 and FY99 with the two-year, $30 million "pilot" program that provided grants and loans for local water distribution system rehabilitation projects. The rationale for the initial program was that funds spent on improving local water distribution systems provide greater regional water quality benefits than spending those same funds for water treatment filtration.

Building on the success of the pilot water financial assistance program, the Phase 1 - Local Pipeline Assistance Program (LPAP) was approved in FY01 to provide 10-year interest-free loans to water system communities primarily for water main replacement or cleaning and lining projects. Under the Phase 1- LPAP, $222 million in loans for local water projects were distributed from FY01 through FY13. MWRA established the Phase 2 - Local Water System Assistance Program (LWSAP) in FY11 to extend the local water loan program through FY20. This expansion of the water loan program added $210 million in interest-free loans for member water communities (including a $10 million allocation specifically for the three Chicopee Valley Aqueduct communities).

New cement-lined water mains

Since FY98, a total of about 400 miles of community water mains have been replaced or rehabilitated via MWRA financial assistance projects. Thirty-eight of MWRA's 45[7] eligible member water communities have participated in the water system loan programs with over $300 million invested to fund local water projects that will help maintain high water quality in local distribution systems. The allocation and funds utilized by each eligible community under the Local Pipeline and Water System Assistance Program are listed on the following two tables (8-5 and 8-6). MWRA's partially supplied water communities received pro-rated shares of loan fund distributions based on their percentage use of MWRA water. Table 8-7 provides individual statistics for the total miles of lined and unlined water main in each member water community.

[7] MWRA has a total of 50 water communities (with Dedham/Westwood Water District counted as one), of which 45 are allocated loan funds under the Local Water System Assistance Program. The five ineligible water communities have special case considerations; these include: Clinton, Leominster (emergency only), and Worcester (emergency only), that receive untreated water from the Wachusett Reservoir; Cambridge, that receives water on an emergency-only basis; and Lynn, that receives water for the GE plant only. Under the initial Local Pipeline Assistance Program, the three Chicopee Valley Aqueduct (CVA) communities (Chicopee, South Hadley FD#1, and Wilbraham) were not allocated loan funds.

Table 8-5

MWRA LOCAL PIPELINE ASSISTANCE PROGRAM ALLOCATION AND FUND UTILIZATION BY COMMUNITY THROUGH JUNE 2013

Community	Community Total Allocation	Funds Distributed Thru Jun 13	Percent Distributed	Unutilized Funds
Arlington	$9,723,620	$6,099,000	63%	$3,624,620
Bedford*	$1,018,610	$1,018,610	100%	$0
Belmont	$4,213,570	$4,213,570	100%	$0
Boston	$61,571,330	$61,571,330	100%	$0
Brookline	$625,090	$0	0%	$625,090
Canton*	$2,080,380	$0	0%	$2,080,380
Chelsea	$5,023,870	$4,825,468	96%	$198,403
Dedham/Westwood* ##	$7,500	$7,500	100%	$0
Everett	$5,429,020	$5,429,020	100%	$0
Framingham	$8,681,800	$8,681,800	100%	$0
Lexington	$1,539,570	$1,539,570	100%	$0
Lynnfield WD	$320,000	$320,000	100%	$0
Malden	$10,244,520	$10,244,520	100%	$0
Marblehead	$6,320,350	$0	0%	$6,320,350
Marlborough*	$1,166,200	$1,166,200	100%	$0
Medford	$9,723,620	$7,212,923	74%	$2,510,697
Melrose	$6,586,590	$6,586,590	100%	$0
Milton	$6,771,800	$6,771,800	100%	$0
Nahant	$1,331,210	$1,111,242	83%	$219,968
Needham*	$1,286,520	$257,304	20%	$1,029,216
Newton	$25,860,190	$25,860,190	100%	$0
Northborough*	$97,180	$0	0%	$97,180
Norwood	$5,139,630	$5,139,630	100%	$0
Peabody*	$838,030	$838,030	100%	$0
Quincy	$15,835,600	$15,835,600	100%	$0
Reading ###	$1,916,000	$1,916,000	100%	$0
Revere	$5,371,140	$3,500,000	65%	$1,871,140
Saugus	$9,029,070	$9,029,070	100%	$0
Somerville	$9,480,530	$9,480,530	100%	$0
Southborough	$81,030	$0	0%	$81,030
Stoneham	$1,736,360	$1,736,360	100%	$0
Stoughton* #	$4,480,000	$4,480,000	100%	$0
Swampscott	$5,602,660	$5,602,660	100%	$0
Wakefield*	$2,524,950	$0	0%	$2,524,950
Waltham	$13,636,210	$2,552,968	19%	$11,083,242
Watertown	$1,736,360	$1,736,360	100%	$0
Wellesley*	$1,279,280	$1,279,280	100%	$0
Weston	$127,330	$127,330	100%	$0
Wilmington* ####	$73,000	$0	0%	$73,000
Winchester*	$665,190	$665,190	100%	$0
Winthrop	$4,167,260	$2,027,600	49%	$2,139,660
Woburn*	$3,454,330	$3,454,330	100%	$0
TOTAL	**$256,796,500**	**$222,317,575**	**87%**	**$34,478,926**

*** Partially Served Communities**

 # Stoughton's total allocation is for eight years; the Town was not an MWRA member water community for the first two years of the Program.

Dedham/Westwood's total allocation is for five years; the Town was not an MWRA member water community for the first five years of the Program.

Reading's total allocation is for five years; FY06 and FY07 as a partially supplied MWRA water community at $142,000/year and FY08, FY09, and FY10 as a fully supplied MWRA water community at $544,000/year.

Wilmington's total allocation is for one year - FY10.

Table 8-6

MWRA LOCAL WATER SYSTEM ASSISTANCE PROGRAM ALLOCATION AND FUND UTILIZATION BY COMMUNITY AS OF JULY 2013

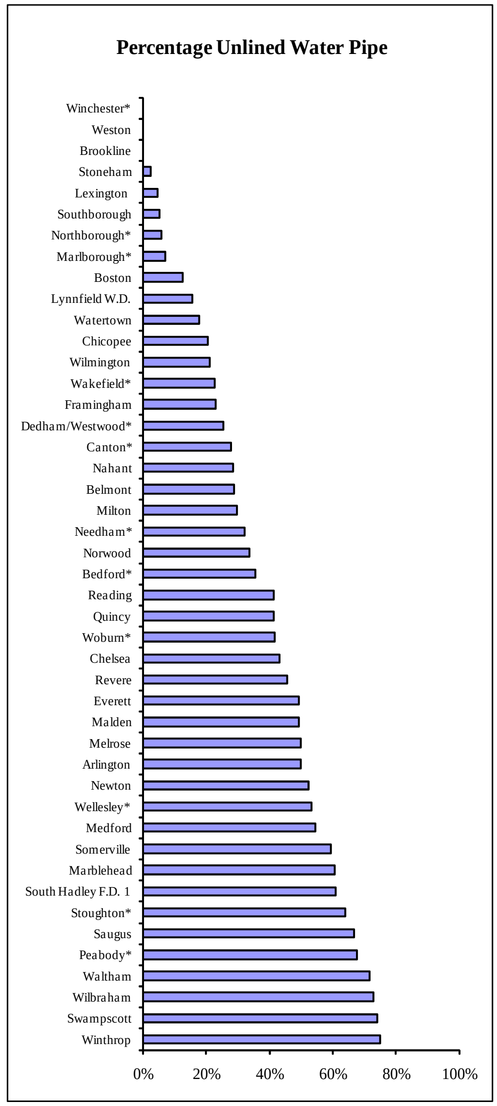
Community	Community Total Allocation	Allocation To Date (Year 4)	Funds Distributed Thru Jun 13	Percent Distributed (Year 4)	Total Remaining Funds
Arlington	$6,225,000	$2,490,000		0%	$6,225,000
Bedford *	$2,418,000	$2,000,000	$1,000,000	50%	$1,418,000
Belmont	$3,477,000	$2,000,000	$1,500,000	75%	$1,977,000
Boston	$38,754,000	$15,501,600	$8,948,040	58%	$29,805,960
Brookline	$3,426,000	$2,000,000		0%	$3,426,000
Canton *	$3,216,000	$2,000,000	$910,000	46%	$2,306,000
Chelsea	$3,814,000	$2,000,000		0%	$3,814,000
Dedham/Westwood *	$503,000	$503,000	$503,000	100%	$0
Everett	$4,672,000	$2,000,000	$1,500,000	75%	$3,172,000
Framingham	$7,357,000	$2,942,800	$2,207,100	75%	$5,149,900
Lexington	$3,024,000	$2,000,000		0%	$3,024,000
Lynnfield Water Dist.	$1,396,000	$1,396,000		0%	$1,396,000
Malden	$7,272,000	$2,908,800	$1,454,000	50%	$5,818,000
Marblehead	$4,237,000	$2,000,000		0%	$4,237,000
Marlborough *	$1,917,000	$1,917,000	$1,283,800	67%	$633,200
Medford	$6,959,000	$2,783,600		0%	$6,959,000
Melrose	$3,988,000	$2,000,000		0%	$3,988,000
Milton	$4,123,000	$2,000,000	$850,000	43%	$3,273,000
Nahant	$1,490,000	$1,490,000	$884,000	59%	$606,000
Needham *	$794,000	$794,000		0%	$794,000
Newton	$13,602,000	$5,440,800	$2,720,400	50%	$10,881,600
Northborough *	$1,048,000	$1,048,000		0%	$1,048,000
Norwood	$4,395,000	$2,000,000	$1,500,000	75%	$2,895,000
Peabody *	$1,089,000	$1,089,000		0%	$1,089,000
Quincy	$10,505,000	$4,202,000	$3,151,500	75%	$7,353,500
Reading	$4,146,000	$4,146,000	$134,000	3%	$4,012,000
Revere	$5,034,000	$2,013,600		0%	$5,034,000
Saugus	$6,621,000	$2,648,400	$1,880,000	71%	$4,741,000
Somerville	$7,419,000	$2,967,600	$682,234	23%	$6,736,766
Southborough	$1,512,000	$1,512,000		0%	$1,512,000
Stoneham	$2,339,000	$2,000,000	$1,000,000	50%	$1,339,000
Stoughton*	$2,506,000	$2,000,000		0%	$2,506,000
Swampscott	$3,755,000	$2,000,000	$249,468	12%	$3,505,532
Wakefield *	$2,325,000	$2,000,000	$1,400,000	70%	$925,000
Waltham	$10,293,000	$4,117,200	$1,320,000	32%	$8,973,000
Watertown	$2,978,000	$2,000,000	$1,500,000	75%	$1,478,000
Wellesley *	$2,350,000	$2,000,000	$241,569	12%	$2,108,431
Weston	$1,625,000	$1,625,000		0%	$1,625,000
Wilmington *	$611,000	$611,000		0%	$611,000
Winchester *	$882,000	$882,000		0%	$882,000
Winthrop	$3,312,000	$2,000,000	$750,000	38%	$2,562,000
Woburn *	$2,591,000	$2,000,000	$1,000,000	50%	$1,591,000
Chicopee	$7,153,000	$2,861,200	$2,085,000	73%	$5,068,000
South Hadley F.D. 1	$1,538,000	$1,538,000		0%	$1,538,000
Wilbraham	$1,309,000	$1,309,000		0%	$1,309,000
TOTAL	**$210,000,000**		**$40,654,111**		**$169,345,889**

* Partially Served Communities

Table 8-7

MWRA LOCAL PIPELINE AND WATER SYSTEM ASSISTANCE PROGRAMS
LINED AND UNLINED PIPE BY COMMUNITY
AS OF JUNE 2013

Community	Total Miles of Pipe	Miles of Lined Pipe	Miles of Unlined Pipe	Percent Unlined
Arlington	132	66	66	50%
Bedford*	85	55	30	36%
Belmont	88	63	25	29%
Boston	1009	883	126	12%
Brookline	140	140	0	0%
Canton*	121	87	34	28%
Chelsea	59	33	25	43%
Chicopee	262	209	54	21%
Dedham/Westwood*	190	141	49	26%
Everett	68	35	34	49%
Framingham	274	211	63	23%
Lexington	157	150	7	5%
Lynnfield W.D.	29	25	5	16%
Malden	118	60	58	49%
Marblehead	80	31	48	61%
Marlborough*	168	156	12	7%
Medford	121	55	66	54%
Melrose	80	40	40	50%
Milton	138	97	41	30%
Nahant	23	16	7	29%
Needham*	133	90	43	32%
Newton	319	151	167	52%
Northborough*	65	61	4	6%
Norwood	118	78	40	34%
Peabody*	170	55	115	68%
Quincy	238	140	98	41%
Reading	110	65	45	41%
Revere	91	50	41	46%
Saugus	125	41	84	67%
Somerville	120	49	71	59%
South Hadley F.D. 1	82	32	50	61%
Southborough	87	82	5	5%
Stoneham	78	76	2	3%
Stoughton*	148	53	94	64%
Swampscott	55	14	41	74%
Wakefield*	114	88	26	23%
Waltham	157	44	113	72%
Watertown	80	66	14	18%
Wellesley*	136	64	72	53%
Weston	105	105	0	0%
Wilbraham	74	20	54	73%
Wilmington	126	99	27	21%
Winchester*	105	105	0	0%
Winthrop	45	11	34	75%
Woburn*	182	106	76	42%
TOTAL	**6,405**	**4,301**	**2,105**	**33%**



*** Partially Served Communities**

Details on the application process, the Program Guidelines, and the Financial Assistance Application are provided on the MWRA Community Support Program web page: http://www.mwra.com/comsupport/communitysupportmain.html. Eligible projects focus on elimination of unlined water mains. For the Phase 2 - LWSAP eligible projects were expanded, particularly for those communities that have demonstrated a commitment to water pipeline improvements. Local projects that rehabilitate water distribution systems, improve water quality, and/or enhance system efficiency are eligible for MWRA financial assistance, as noted below:

- Water main cleaning and lining of unlined water mains;
- Replacement, sliplining, or abandonment of unlined water mains;
- Replacement or abandonment of asbestos cement pipe or other water pipeline work performed for water quality purposes;
- Identification and replacement of water service connections constructed of lead or other water services in poor condition;
- Looping of dead-end water mains;
- Water valve and hydrant installation or replacement;
- Water storage tank installation, rehabilitation, or replacement; and,
- Engineering planning, design and construction services associated with the above items.

To provide communities some flexibility with regard to water system rehabilitation needs, additional community projects (Tier Two Projects) that target water system efficiency are also eligible for Phase 2 - LWSAP loan funding. To emphasize the Program's goal of improving water quality, the amount of LWSAP funds that may be used for Tier Two Projects shall be restricted to the community's percent of lined water main miles times the community's total LWSAP allocation. Tier Two eligible projects include:

- Water meter purchase and installation;
- Water meter reading system purchase and installation;
- Water booster pump station installation and/or upgrades;
- GIS mapping and system modeling; and,
- Engineering planning, design and construction services associated with the above items.

Commitments to provide interest-free loans for local water projects are issued by the MWRA in the form of a financial assistance and loan agreement subject to the availability of Program funds. Financial assistance is distributed quarterly, on or about: February 15, May 15, August 15, and November 15. Complete community applications are due to MWRA one month prior to the proposed loan distribution date. The financial assistance award is electronically transferred into a Massachusetts Municipal Depository Trust (MMDT) account established by the community. All financial assistance funds, together with the earned interest from the MMDT account, are required to be expended on approved community water system rehabilitation projects. Both the community and the MWRA receive monthly MMDT account statements to track account expenditures.

Even with the substantial progress made over the last 15 years, MWRA estimates that over 2100 miles of community water main remain unlined, representing a future community water main replacement/rehabilitation cost of over $1.0 billion. For master planning purposes, staff recommend future third and fourth phases of the Local Water System Assistance Program be considered for funding in future CIPs. Each new phase is recommended to provide $210 million in interest-free loans (with 10-year loan repayments) during the FY21-30 and FY31-40 time periods. MWRA staff will continue to work cooperatively with the Advisory Board to identify potential program improvements which may be recommended to the Board for approval.

Table 8-8 lists the net costs of the Local Pipeline and Water System Assistance Program (Phases 1 and 2) that are programmed in the FY14 CIP, as well as, the net costs of additional Phases 3 and 4 that are recommended for consideration in future CIPs.

Projects in the FY14 CIP:

- Phase 1 - Local Pipeline Assistance Program is programmed in the FY14 CIP at a net revenue of $87 million in the FY14-23 timeframe. The net cost of the Phase 1 program includes only loan repayments since Phase 1 loans were completed in FY13.

- Phase 2 - Local Water System Assistance Program is programmed in the FY14 CIP at a net revenue of $31 million in the FY14-30 timeframe. The net cost of the Phase 2 program includes $176 million in additional 10-year interest-free loans and $207 million in offsetting community loan repayments.

Projects Recommended for Consideration in future CIPs:

- Given the greater than one billion dollars anticipated to be needed for future community water main replacement/rehabilitation cost, staff recommend continues systematic investment in local water system infrastructure through MWRA financial assistance. For master planning purposes, staff recommend future third and fourth phases of the Local Water System Assistance Program be considered for funding in future CIPs. Each new phase is recommended to provide $210 million in interest-free loans (with 10-year loan repayments) during the FY21-40 and FY31-50 time periods. Because loan distributions are offset by community repayments over time, the net CIP budget of each recommended loan phase is zero. Prior to expansion of the current program, coordination with the MWRA Advisory Board is required to develop a recommendation for Board of Directors consideration.

Pressure Zone Issues and Recommendations

8.7 Boston Low and Northern Low Service Areas

The Low Service area accounts for approximately 23% of MWRA use and provides water to low lying areas of Boston (Boston Low) and five suburban communities to the north (Northern Low). The Low system is the oldest part of the metropolitan system. As such, it has been the focus of much pipeline renewal work, particularly in the vicinity of Chestnut Hill.

The Boston portion of the service area is normally supplied from Loring Road Covered Storage (elev.200') by two of the large diameter Weston Aqueduct Supply Mains (WASM 1 & 2). In addition, Operations can feed one of the Boston meters from the Spot Pond Supply Mains from the Shaft 8 PRV.

The Northern Low Service (NLS) area is supplied by high service tunnel water which is reduced in pressure and distributed through the Spot Pond Supply Mains extending north from Chestnut Hill to meters in the northern part of the Low system. Shafts 7, 7B, 8, 9, and 9A all have pressure reducing valves (PRVs) which provide for the noted pressure reduction. The NLS PRV provide for great redundancy due to the number of pressure reducing valves, and their location throughout the service area. Because the Low service area includes those areas at the lowest elevations, hydraulic deficiencies in this area are rare. The Nonantum Road PRV also allows the Northern Low to also be fed from WASM 4.

The Spot Pond Covered Storage Design-Build project is currently under construction in Stoneham, MA. This storage facility was identified as part of the original *Water Distribution System Storage Study* and will replace 20 MG of the storage previously available from the Spot Pond Reservoir. The tanks will be filled at night via the Nonantum Road PRV and can be used in conjunction with Loring Road to meet peak demands for the Low Service system.

Figure 8-10

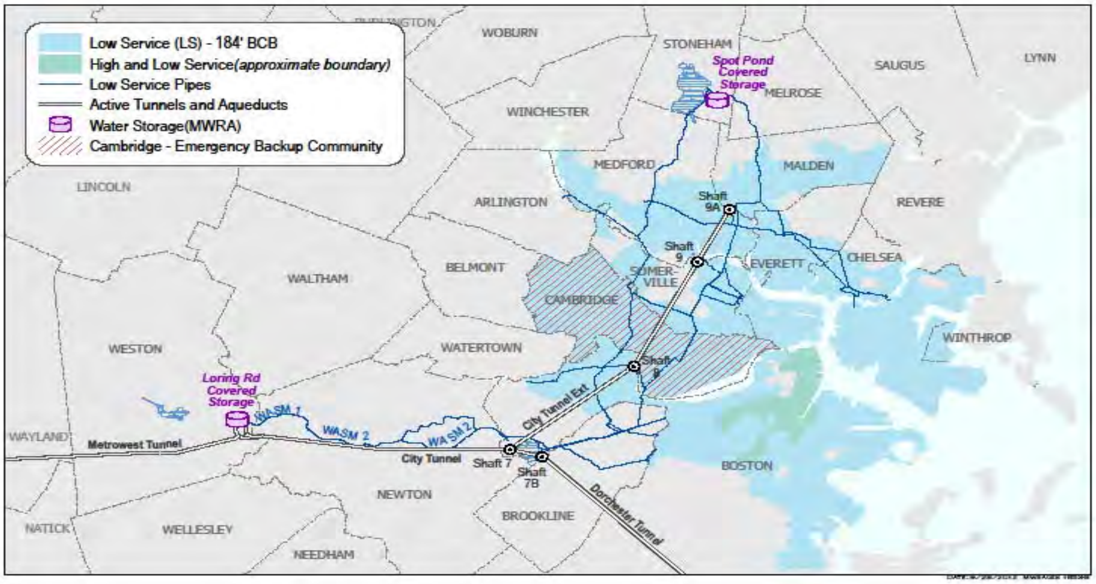


Figure 8-10 shows the communities and key infrastructure of the Low System including the Spot Pond Covered Storage Facility which is currently under construction in Stoneham, MA. MWRA serves as an emergency back-up for the City of Cambridge. This section of Winchester also can be partially supplied through a metered connection from Spot Pond to their local water treatment plant.

<u>Delivery System Condition and Ongoing Work</u>:

The pipes in this service area include the oldest sections owned by the Authority including some pipes that date to the 1840's. Much of the pipe rehabilitated to date has been is old unlined cast iron and some sections that have deteriorated to the point of removal from service due to the risk of breaks are scheduled for replacement or abandonment. Substantial work has been completed since MWRA's inception to rehabilitate WASM 1 and WASM 2 primarily using cleaning and lining techniques. The Low Service supply to the downtown Boston area has no significant pressure problems when fully in service.

The rehabilitation of the 100 year old East and West Spot Pond Supply Mains was completed in 2008. These mains serve as distribution mains to the eight communities in the Northern Low system and can provide emergency back-up to the Gillis Pump Station. The East Spot Pond Supply Main is 61,000 linear feet of mostly 48" diameter pipe and the West Spot Pond Supply Main is approximately 53,000 linear feet of 48-inch and 60-inch pipe.

In September 2006, the Shaft 9A PRV in Malden malfunctioned to allow the discharge hydraulic gradient in the Northern Low to rise from a normal of about 180 feet to a brief spike reaching over 220 feet. This pressure spike and additional ones that followed caused over forty breaks in the five communities of Chelsea, East Boston, Medford, Malden and Everett. A second PRV at Shaft 9A was brought on line and experienced similar fluctuations. An alternate PRV was brought on line at Shaft 9 and has performed well. This illustrates the value of the operational flexibility provided by the redundant PRVs at the tunnel shafts.

Another older pipeline in this pressure zone requiring a mix of replacement and cleaning and lining work is Section 8 in Malden and Everett. Section 8, a 48" cast iron main, in excess of 100 years old, had a catastrophic failure in October, 2002. A 22 ½ degree bend failed along its length, causing extensive damage to the street. Service to the NLS was temporarily affected until the break was isolated. As part of the existing CIP, the pipeline will be cleaned and lined and all defective or inoperable valves replaced in the 7,500 feet of 48-inch pipe and new 36-inch ductile iron main will replace 9,722 feet of the 42-inch deteriorated cast iron main in Everett to the Mystic River Bridge in Chelsea. Design is expected to start in July 0f 2017 with construction now scheduled to be completed in 2022 but design will commence in July 2016 to rehabilitate and strengthen Sections 37 (3,550 linear feet of 36-inch cast iron main) and 46 (2,500 linear feet of 36-inch cast iron main) which provide service to East Boston with construction scheduled to be completed in 2019. Section 38, the 36-inch ductile iron pipeline under Chelsea Creek is assumed to not require rehabilitation.

The Northern High line (97A) was completed to improve service to Orient Heights, however, a new PRV will allow this line to provide redundant service to East Boston including Logan Airport.

Recommended Projects: Low Service

The existing CIP project to rehabilitate Section 8 must be completed prior to these two projects being done.

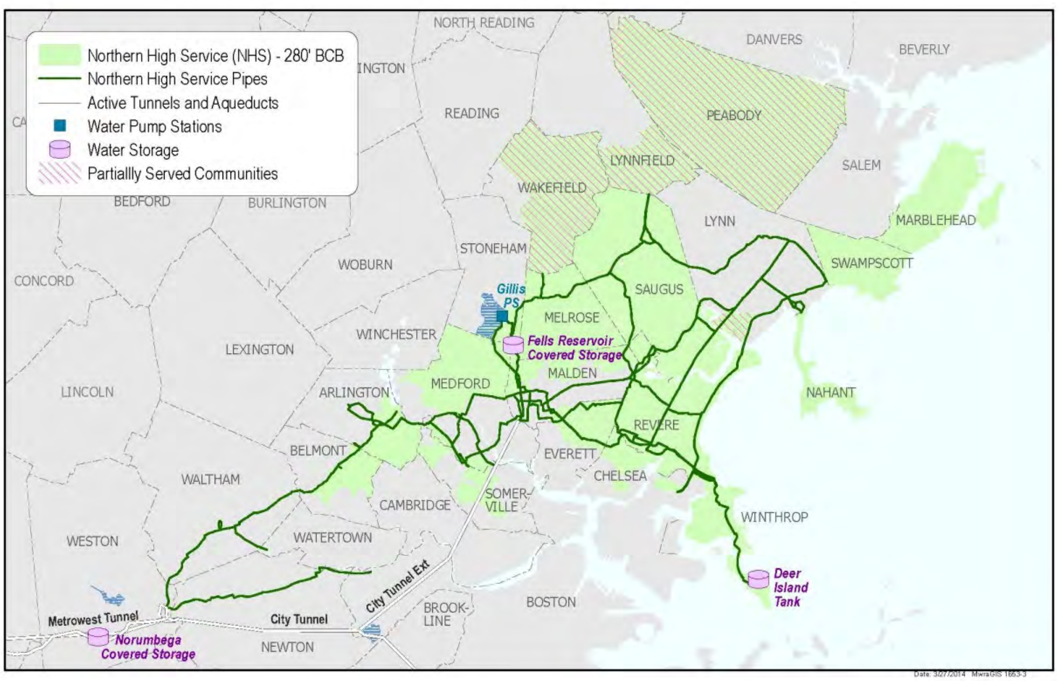
- Design and Construction for replacement and rehabilitation of 5,000 linear feet of 36-inch pipe on Section 66 and replacement and rehabilitation of 5,000 linear feet of 30-inch pipe with 36-inch pipe on Old Mystic Main. Abandonment of 14,000 linear feet of 150 year old 24-inch cast iron main. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $8.2 million and, in conjunction with the project below, should be scheduled in the FY24-33 time period.

- Design and Construction for rehabilitation of the remaining portion of Section 57 in Riverside Avenue (approximately 8,000 linear feet) in Medford along with rehabilitation of the portion of Section 20 of the Metropolitan Sewer which is in the immediate proximity. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $21.4 million and this work should also be done in the FY24-33 time period.

8.8 Northern High Service

The Northern High Service zone is the largest geographical service zone and is located north of Boston. Water is supplied from Norumbega Covered Storage Facility (elev. 282') via the City Tunnel and City Tunnel Extension and distributed to 20 communities by gravity flow. The remaining three communities, Melrose and portions of Stoneham and Saugus, are supplied from the Gillis Pumping Station by pumping to the Fells Reservoir Covered Storage (elev. 270'). This sub-area accounts for approximately 2.8 MGD of the 29.8 MGD provided to the Northern High on an average day (2011). However, this does not include any flow to Wakefield during 2011 as the Town used local sources and flow from MWRA's Northern Intermediate High Service area. The Northern High system also provides service to MWRA facilities on Deer Island.

Figure 8-11



Delivery System Condition and Ongoing Work:

Since this service is so large and distant from Norumbega reservoir, it had historically experienced the widest pressure fluctuations during summer peak flows. This has improved with the increased grade line of Norumbega Covered Storage. The northeastern corner of the service area, which feeds Marblehead, Swampscott and Nahant, was significantly strengthened by the completion of Section 91 through Lynn. The southern part of the Northern High, including Chelsea, Everett, Orient Heights and Winthrop, has already been improved by the addition of reinforcing pipelines including 97A in 2009. Previously marginal areas are no longer a factor. The Deer Island tank came on line in 1995 and has improved the reliability of service to Winthrop and on Deer Island.

Fells Gravity Operation

Normal operation of the Fells system is through the use of the Gillis pump station and the Fells Covered Storage Facility (FCSF). Water is normally pumped using one of three pumps at Gillis dedicated to the service area. Communities served by the Fells service area include Melrose, Saugus, Stoneham, and Wakefield. The hydraulic grade line of the city tunnel system varies seasonally, due to overall system demand. During the summer peaks, the grade line can drop below 260’ BCB during peak daytime periods; during the winter season, the grade line can remain significantly higher. Use of the Fells service area maintains the hydraulic grade line between 262’ BCB and 270’ BCB thru the use of the pumps at Gillis and the covered storage facility. Activation of the Norumbega Covered Storage facility has provided for a much more stabile hydraulic grade line in the tunnel and surface piping systems. There are approximately 10 months during the year that the FCSF can be filled via gravity from the tunnel system. The summer peaks still create too much of a drop in the hydraulic grade line to enable gravity supply 12 months a year. For those 10 months or so when the hydraulic grade line is high enough, a SCADA controlled valve will be used to control the elevation of the FCSF. The valve is programmed to open and close on water elevation in the FCSF. The operation of the valve replicates the filling of the FCSF identical to the use of the pumps at the Gillis pump station. A successful trial operation was conducted in the spring and early summer of 2012, using manual control of the valve. A new actuator has been installed on the valve, and new programming applied to the valve operator such that it will be used to fill the FCSF. The programming is designed to monitor the water elevation at Fells, such that if the elevation drops a foot below the normal valve opening position, the valve will close, and one of the Fells pumps at Gillis will activate.

MWRA’s target grade line analyses completed in 2005 determined that potential hydraulic deficiencies may still be a factor at several meters in six communities (Boston-Orient Heights, Chelsea, LWD, Medford, Melrose and Saugus). In Medford, Melrose, and, in particular, Saugus, these communities have high ground elevations which are difficult to serve by gravity. Specifically, Saugus has experienced hydraulic deficiencies due to continued housing development at higher elevations in the northwest part of town. Typically, it is the responsibility of the local community to address these deficiencies through booster pumping (as Melrose has done). However, in Saugus, MWRA has adjusted operation of our system to better accommodate the Town’s needs. Meter 205, at the intersection of the Lynn Fells Parkway and Main Street can be fed from Section 70 (Fells gradient) and Section 72 (NHS gradient). The normal supply to Meter 205 is from Section 70, which is the higher gradient (pressure).

For Lynnfield, the new Lynnfield pipeline was completed in 2013. This addressed the insufficient capacity of the 8-inch MWRA line previously used to feed the District. The project connects Lynnfield's Meter 169 to Section 70 in Saugus and includes 4,700 linear feet of new 24-inch main and 1,800 linear feet of 36" main. In addition, 6.000 linear feet of 12-inch water main was constructed for the Town of Saugus under a cost sharing arrangement.

Gillis Pumping Station is one of the oldest stations in the system but it was substantially overhauled and upgraded in the 1990's. In addition a new suction pipeline to the Station from the City Tunnel shaft in Malden was installed which provides water at a higher head than was provided by Spot Pond (which now serves only as an emergency back-up). These improvements have facilitated the ability to transfer water between the low and high service systems and allow the full use of the 20 MG Fells Reservoir Covered Storage facility which came on line in Fall, 1999. As recommended in the 2008 *NIH Assessment and Concept Plan on Short-Term Risk Reduction Strategies*, variable frequency drives (VFDs) will replace the constant speed motors on two pumps. This will allow the pumps to operate over a much larger flow and head range further increasing the operational flexibility of the Gillis Station.

New Spot Pond Pump Station

As part of the new Spot Pond Storage Project for the Low system, a pump station will also be included in the site. The new pump station will have similar operational capabilities as does Gillis pump station and will provide redundancy for the Gillis Station. Gillis currently supplies two service areas from the one station – five pumps are dedicated to the Northern Intermediate High (NIH) service area, and three pumps are dedicated to the Northern High Service/Fells (NHS/Fells) service area. The Bear Hill tank and the Fells Covered Storage Facility (FCSF) are the tanks in the two respective service area. Normal suction to the pump station is from Section 99, which is part of the NHS area. Gillis can also pump from the Northern Low Service (NLS) piping, which is connected to the station from the Spot Pond Bypass line, and Sections 7 and 12. Gillis can also be used to pump water from Spot Pond on an emergency basis, and serve the entire NHS area. The new Spot Pond pump station will also be capable of the same operation, and will have the benefit of the immediately adjacent 20 million gallon Spot Pond storage tank. The operation of the new station will be integrated into the day to day operation of Gillis to the NIH service area, similar to the operation of Hyde Park and Newton Street pump stations in the Southern Extra High (SEH) service area, and Brattle Court and Spring Street pump stations in the Northern Extra High (NEH) service area. The NIH pumps at Spot Pond and Gillis will be programmed to run in a lead/lag fashion to provide redundancy that has been lacking to the NIH service area.

The 1993 Master Plan repeated the *Water Distribution System Storage Study* recommendation that a new storage tank with a useable volume of 24 MG be constructed in the vicinity of the Lynn/Saugus border in order to improve hydraulics and reliability for the Northern High system. In general, as noted in the *2006 Water System Master Plan*, construction of Section 91 resolved major hydraulic concerns for this part of the Northern High system and the construction of the Fells Covered Storage Facility also alleviated some of the concerns relative to reliability. It was also envisioned long-term that more storage (in addition to the 20 MG constructed to date) would be built at the

Fells Reservoir site. This storage was proposed, in part, because it would work in concert with the previously proposed Northern Tunnel Loop which is no longer MWRA's preferred method for transmission system redundancy. At this point, these projects are not being recommended.

Pipelines

The Northern High Service has a wide range of pipe ages and materials. Of particular concern are the remaining unlined cast iron mains and the larger diameter steel mains which serve as major transmission mains for this service area. The Northern High system contains a significant amount of the remaining unlined cast iron pipe and these mostly small diameter unlined cast iron pipe can be a contributor both to water quality problems as well as pressure problems. MWRA's initial capital budget focused on rehabilitation of larger pipes and on resolving immediate, known piping problems. More recently, focus has also turned to projects to address redundancy shortfalls in the distribution system. However, it is critical that MWRA continue to address the remaining older cast iron pipe in the system. Recommendations in this section and other service areas identify remaining projects that should be gradually moved into the CIP. Many of these projects had been removed from previous CIPs due to budgetary concerns; however, systematic replacement is still critical. Future potential changes in water quality regulations (see Chapter 5) will likely focus on the distribution system and this unlined, highly tuberculated pipe needs to be systematically replaced.

The Northern High also contains some of the remaining steel pipe constructed approximately 75 years ago which has tended to corrode and leak frequently. Although some sections, as mentioned above, have been replaced in this service area, Sections 70 and 71, and 79 remain to be addressed. These sections are predominantly steel but are comprised of many different sections of pipe materials. The FY14 CIP contains $1 million for an initial planning study to begin in July 15 that would address the appropriate ways to stage such a significant rehabilitation project. However, if staff resources are available, it may be possible to do this work in-house.

Work completed to date to address older pipelines includes Revere and Malden pipeline improvements such as the significantly corroded 18,900 linear feet of steel pipeline (Section 53) in Malden and Revere which was completed in 2009. Additionally, the undersized Section 53A will be reinforced by a new 3,000 linear feet 60-inch diameter pipeline and Section 68 will be reinforced with 850 feet of 48-inch pipeline. The FY14 CIP calls for design to begin in 2014 and for construction to commence in 2016. The Shaft 9A-D Extension will provide a more reliable connector to the Section 99 pipeline that serves as the suction line to the Gillis Pump Station. This work is proposed to start design in 2017 and construction in 2019.

Section 27 is a 12-20-inch cast iron main (approximately 120 years old) that serves the communities north of Lynn. In-house design work was previously completed and significant rehabilitation and pipe replacement has also been completed in-house. Although the FY14 CIP carries approximately $900,000 for additional work beginning in 2018, an in house analysis should be done to determine what work remains to be done.

Section 26 in this same area is currently shut down (section underneath the Saugus River) due to a leak but is scheduled to be replaced as part of DOT replacement of the bridge structure. The schedule for this work is uncertain although work on the temporary replacement bridge is underway.

Section 97A was completed in 2009. This project installed approximately 2,000 feet of 20-inch water main, a rehabilitated metering station and a new PRV. This project also addressed existing pressure deficiencies in the Orient Heights area. The PRV will also allow this line to serve critical parts of the Boston Low (Logan Airport) in emergencies. The completion of 97A improves the MWRA's operational flexibility for moving ahead with the Section 8 work in the Northern Low system.

Another project recently completed under the Connecting Mains Project is the rehabilitation of Sections 18, 50 and 51. These mains provide high service water to Medford and a majority of the high service area of Somerville. These pipes include approximately three miles of cast iron water main with an age range of 80-100 years old. Prior to rehabilitation, carrying capacity is these mains had been reduced to approximately 50 percent of the original design capacity due to tuberculation. However, the existing pipes were structurally sound allowing these pipes to be rehabilitated by cleaning and cement mortar lining. Additionally, many of the valves were undersized or inoperable, both causing flow restrictions and limiting MWRA's ability to isolate portions of these mains in the event of a break, leak or for maintenance. The project replaced 12 mainline valves, retrofitted blow-off valves to eliminate cross connections and replaced Meter 32 serving Somerville. This project is a key element in allowing the future shut-down of WASM 3 during the pending replacement and rehabilitation of that pipe.

A portion of Section 50 is also recommended for rehabilitation under the Spot Pond Supply Mains project in the FY14 CIP. Design is scheduled to start in July of 2016 with construction to follow in July 18. This portion of Section 50 consists of several hundred feet of 20-inch cast iron main which sits on exposed pilings and the design and construction costs are estimated at $2 million.

Recommended Projects: Northern High Service

The recommendations for the Northern High system address an immediate need for pipe rehabilitation to preserve redundancy; the need to continue the systematic cleaning and lining of old cast iron mains; and the rehabilitation of steel pipe nearing the end of its expected life. The following projects were all identified in earlier MWRA CIP's but were eliminated for budgetary reasons. The projects are configured geographically as previously identified. However, as in the past with NHS improvements, project groupings and/or schedules can be modified to address local community issues or paving concerns. It is expected that Water Engineering will review these project groupings prior to initiating design work on any of these projects and regroup them as necessary to reflect other project schedules. The key, however, is the continued progress to eliminated older unlined mains.

- Rehabilitation of Section 56 which is currently isolated at the General Edwards Bridge due to excessive leaks. This is a 30-inch unlined steel pipe approximately 75 years old. This project was previously grouped in the project below (rehabilitation of the coastline mains) as part of elimination of old unlined pipe. However, due to Section 26 being out of service, it is recommended that design of Section 56 move forward as soon as possible to ensure a level of continued redundancy to the North Shore communities if there are failures in any of Sections 91, 87 or 72. The cost estimate for this work is $10 million and it is recommended that design work begin in July 2015. Given site constraints, it is assumed that directional drilling should be considered as a construction option.

- Pipeline rehabilitation of the small diameter unlined cast iron along the coastline from East Boston north to Lynn. This includes Sections 54, 55, and 69. Although these cast iron pipes are not as old as some of the other pipes in this service area (1932 and 1951 for Section 69), the C-values associated with these pipelines are estimated to range from 67-73 indicating that the 20-24-inch mains are severely corroded. The cost of this work is estimated to be $16.3 million. This is recommended for the FY20-25 time period.

- Pipeline rehabilitation of NHS Sections 13-18 and 48-unlined cast iron (except Section 48 which is unlined steel) with identified hydraulic restrictions. Sections 13-18 were generally constructed in the 1896-1903 time period and have C-values estimated to be as low as 57 along much of the area but ranging higher in other areas. Based on the analyses completed to rank pipelines, portions of Sections 14, 15, 17 and 18 were all in the top twenty of worst ranked sections. During design, the mix of cleaning and lining versus replacement of any seriously deteriorated segments can be determined. Section 48 is 30-38-inch diameter steel pipe constructed in 1930 with C-values of approximately 75. The estimated cost for design and construction is $18.4 million. This work is recommended for the FY29-33 time period.

- Pipeline rehabilitation of NHS Sections 33, 49, 49A, 50 in Revere and Malden at a cost of approximately $8 million. These are smaller diameter unlined cast iron mains ranging in age from 85 to over 100 years old in age and with C-values in the 60-70 range. Based on historical leak information and C-value, portions of Section 33 ranked in the top ten worst pipe segments in the analyses completed. This work is recommended for the FY 29-33 time period.

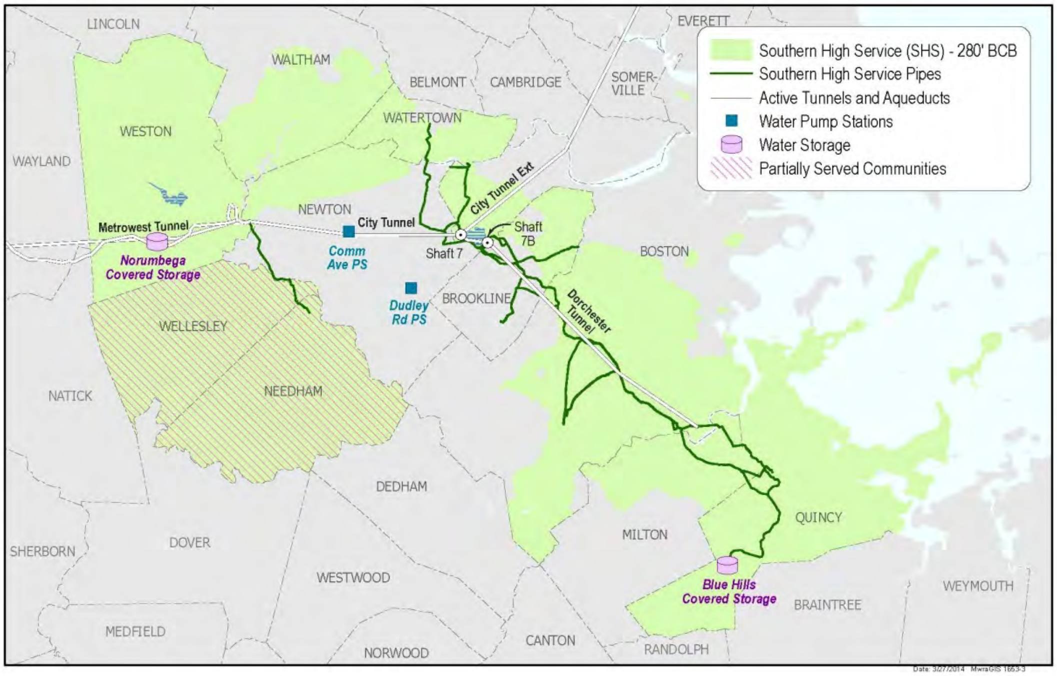
- Rehabilitation of the major unlined steel mains that serve the Northern High. This includes NHS Sections 70 and 71 and 79 which consists of more than 10 miles of corroded pipeline in Stoneham, Saugus, Melrose and Lynn. Design and construction for rehabilitation of these mains could extend over a 10-20 year period and will need to be carefully phased. Moving forward with rehabilitation is expected to extend the life of the pipe and postpone need for more costly pipe replacement. The CIP currently contains a planning study at a cost of $1 million to evaluate the appropriate sequencing of work prior to proceeding with rehabilitation. It is possible that such a study could be completed in-house if staff resources are available. The estimated design and construction costs for the rehabilitation work is $35.7 million and should be initiated in the FY 30-36 time period.

8.9 Southern High Service

The Southern High Service Area has the greatest average daily water demand at 51.1 MGD. Due to its configuration, the Southern High can be characterized in three sub-areas. A small sub-area includes two communities (Needham, Wellesley) supplied by Section 80 which is directly off of the Hultman/MWWST system. A second sub-area is served off of the Norumbega Supply lines (WASMs 3 and 4). This includes Arlington, Belmont, Newton, Waltham and Watertown. In total, during 2011, these communities had a 7.1 MGD average daily use from the WASM lines (in addition to the 51.1 MGD noted above). Weston is served at the same grade line but it is not considered part of the Metropolitan system and is not included in the 51.1 MGD total above.

The third sub-area includes that area served off of the Dorchester Tunnel. This includes parts of Boston (Brighton, downtown Boston, Dorchester and Roxbury), Brookline, Milton and all of Quincy. The older pipes in this system were constructed to work with the earlier aqueduct systems, the Cochituate and Sudbury, and thus, piping in the Chestnut Hill Vicinity is both complicated and, given its age, in need of extensive rehabilitation. The 2011 average day demand for this area was approximately 48 MGD of the above total. This second area of the Southern High system can only be served off of Shaft 7B on the Dorchester Tunnel. If the Dorchester Tunnel were to go out of service, it would be necessary to activate the Sudbury Reservoir system, transport water via the Sudbury Aqueduct to the Chestnut Hill Reservoir and use the new emergency pump station at Chestnut Hill to pump non-potable water to the Southern High system.

Figure 8-12



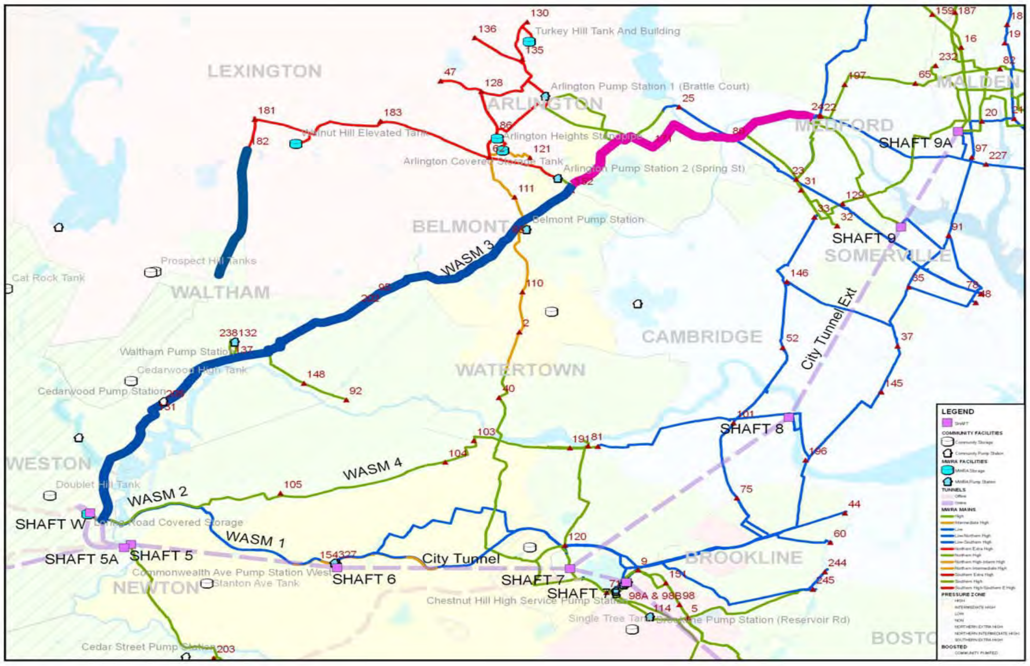
Delivery System Condition and Ongoing Work:

One ongoing concern is that Section 80, which supplies Needham and Wellesley, was constructed with a tar epoxy lining. Since the communities it serves primarily rely on local supplies, the line is not in regular use. Flushing of the line by the local communities prior to its activation is necessary to reduce the potential for customer complaints. This main has also experienced several leaks. The FY14 CIP contains approximately $9.3 million for the design and construction to clean and line 16,200 linear feet of pipeline through Newton, Wellesley and Needham along Route 128/95 to remove tar epoxy lining. This lining will reduce the level of phenols and mitigate public health concerns and maintain consumer confidence. A temporary transmission main would need to be provided during construction because Section 80 would need to be taken off line for the duration of the construction phase. Design and construction is a five year duration and staff recommend that it is currently scheduled to begin in 2017. However, the timing and scope of this rehabilitation is potentially impacted by the outcome for the southern part of the metropolitan system redundancy work that is ongoing. As recommended alternatives for that project are developed, refinements may be required to the Section 80 rehabilitation project.

For the communities served off of the Norumbega Supply Lines, specifically WASM 3, the eleven mile long, steel WASM 3 pipeline remains a significant concern due to corrosion. The pipe, which was built in the 1920's, requires frequent repairs and rehabilitation is critical. This supply line carries high service water from the 7-foot diameter branch of the Hultman Aqueduct to community connections and MWRA pumping stations serving the Intermediate High, the Northern High and the Northern Extra High pressure zones. It extends from the Hultman branch to Shaft 9 in Medford and supplies approximately 230,000 customers over all. There is no back-up for WASM 3, which is the sole source of supply for the higher elevations of Waltham, Belmont, Arlington, Lexington, Bedford and Winchester. A new Waltham connection to the Northern Extra High system is required to allow WASM 3 to be shut down for rehabilitation. This work will be done as part of the Section 36/WS/Waltham Connection project. This project includes replacement of approximately 5,200 linear feet of approximately 100 year old 16-inch diameter cast-iron pipe from the Brattle Court pumping station to the Arlington Heights Standpipe, rehabilitation of approximately 5,795 linear feet of the Watertown Section, a new 11B interconnection to WASM 3 and construction of 8,800 linear feet of a new connection to Waltham from the Northern Extra High service area.

The 2006 Master Plan recommended that a CIP placeholder value of $100 million be included to support redundancy planning for the Metropolitan system. The goal of the planning work begun in 2008 was to re-examine redundancy options. Consideration of a full tunnel loop was part of that review, but given the significant decreases in system demands, the Consultant was also asked to review the existing system and current and proposed CIP projects to see whether there were ways to use existing or modify proposed facilities to develop redundancy alternatives that would optimize use of the existing system. The northern portion of the work entails replacement of the 60-inch diameter sections of WASM 3 with 72-inch diameter pipe north to Spring Street; rehabilitation of the remainder of WASM 3 and, construction of a 36-inch pipeline to Waltham. Design began in 2013. Construction will be divided into three construction packages with the first to begin in 2017 with work on all three construction contracts expected to be complete in 2024. Siting is expected to be difficult since the existing line traverses many densely crowded areas. Tunneling in localized areas may be a viable alternative.

Figure 8-13



For the area of the Southern High served off of the Dorchester Tunnel, pressures generally have not been a problem since the completion of the tunnel in the 1970's. Additionally, the former pressure complaints and peak hourly pressure problems at higher elevations experienced in the City of Quincy (Hospital Hill, Penns Hill and the vicinity of Nut Island) have been alleviated by the completion in 2009 of the 20 million gallons of storage at Blue Hills. This project has increased pressures during peak flows and provided stored treated water closer to the demand.

The Southern Spines Distribution Mains project includes both the rehabilitation of existing pipe and construction of new pipeline segments. Section 22, a steel pipeline, goes from Boston through Milton and into Quincy and has been a significant maintenance concern over time, due to leaks. This is exacerbated by those parts of the pipeline that travel through saltmarsh. The southern portion of Section 22 was rehabilitated in 2005 and the northern section is proposed to be rehabilitated with a planning/EIR phase beginning in 2016. Section 22 North is expected to include rehabilitation of 17,300 linear feet of 48-inch main.

The Southern Spines project also included construction of 4,400 linear feet of new 48-inch main from East Milton Square to Furnace Brook Parkway in Milton and Quincy and replacement of Sections 21 and 43 with 9,200 linear feet of new 48-inch water main from Dorchester Lower Mills in Boston to East Milton Square (Section 107). The activation of Section 107 provides critical redundancy with a pipe loop to the Blue Hills Covered Storage Tanks from the tunnel system. This project has provides sufficient capacity, improved water quality (maintaining chlorine residual in the system) and provides a new level of redundancy for the Southern High Service communities. The hydraulic grade line to Milton and Quincy also improved slightly. In addition, as part of this project, 1,500 linear feet of existing mains were cleaned and lined and three new community revenue meters and additional valves were installed.

The Chestnut Hill area is in many ways the nexus of the water system. The City Tunnel divides into two branches: the City Tunnel Extension going north to supply the Northern High System, Northern Intermediate High System and the Northern Extra High System and the Dorchester Tunnel, which goes south to feed the Southern High System and the Southern Extra High System. Shaft 7 on the City Tunnel is located in this area and Shaft 7B on the Dorchester Tunnel is also located in this area. At each of these shafts, newer pipes extend to connect with the older pipelines of the Boston Low Service System, the Northern Low System and the Southern High Service System.

The older pipes in the area were originally designed to be supplied from the Cochituate and Sudbury Aqueducts, the Chestnut Hill Reservoir, or the Chestnut Hill High Service and Low Service Pump Stations. None of these facilities are presently in normal use and a new underground pump station, completed in 2001, has replaced the Chestnut Hill Stations. The pipe network in this area is both old and complex and was not designed to take water from the two tunnel shafts that are the present sources of potable supply. Since MWRA's inception, changes to better connect these tunnel shafts with the surface pipe network have involved construction of new pipes and abandonment of some old pipe sections.

However, the Southern High System can still only be supplied from Shaft 7B. If the Dorchester Tunnel were out of service, it currently would be necessary to activate the Sudbury Reservoir System and transport water from there via the stand-by Sudbury Aqueduct to the stand-by Chestnut Hill Reservoir and from there, use the new emergency pump station to pump water from the Reservoir to the Southern High System. This water would not be potable and a boil order would be necessary. Completion of the remaining portion of the Chestnut Hill Connecting Mains project would allow potable water to be supplied to the Southern High System. Because the actual configuration of these connections is dependent upon the final recommendations for long-term redundancy for the Metropolitan tunnel systems, the Connecting Mains project has been moved under the Long Term Redundancy project in the CIP with construction currently scheduled to begin in January 2020.

Commonwealth Avenue Pump Station was upgraded as part of the initial series of improvements during the 1990's and the current CIP includes funding for future pump station rehabilitation beginning in July 2019. The Dudley Road Pump Station has been rehabilitated by in-house staff. Dudley Road is used when the PRV that functions as the control valve to Newton's Oak Hill tank is unavailable.

Other projects that have been completed since the 2006 Master Plan include:

Heath Hill Road Pipe replacement: These pipelines supply water to Brookline, Boston and to the SEH system and have been subject to severe corrosion as noted above. Work was completed on Sections 58, 20 and 19 which entailed rehabilitation of approximately 11,000 feet of 48-inch diameter and 10,000 feet of 36-inch diameter segments. Work was also completed on the replacement of 820 feet of Section 52 with a new 48-inch diameter pipe. The remaining work on Section 52 entails the cleaning and lining of 11,500 feet of 54-inch steel pipeline as well as associated valve replacement. Section 52 is a 79 year old steel main extends from the Chestnut Hill Pump Station to Sections 19, 20 and 58 and provides suction to the Newton Street Pump Station.

Walnut Street Pipeline Rehabilitation: This project included the rehabilitation of approximately 7,900 feet of 48-inch unlined cast iron main which is some of the oldest pipe in the system. The hydraulic carrying capacity has been greatly reduced and C-values are estimated to be very low (C-value of 60). The hydraulic gradeline at Meter 5 in Boston is not adequate under max day demands (the Parker Hill area). Along with the rehabilitation of the Walnut Street Line, the project includes relocating Meter 5 to the Boston line (currently in Brookline) and installing a PRV upstream of Meter 5's new location which will connect the Walnut Street Line to the Boylston Street Line. This allows service to Meters 244 and 245 in Boston in the event that the Boylston Line is shut down for any reason.

<u>Recommended Projects: Southern High Service</u>

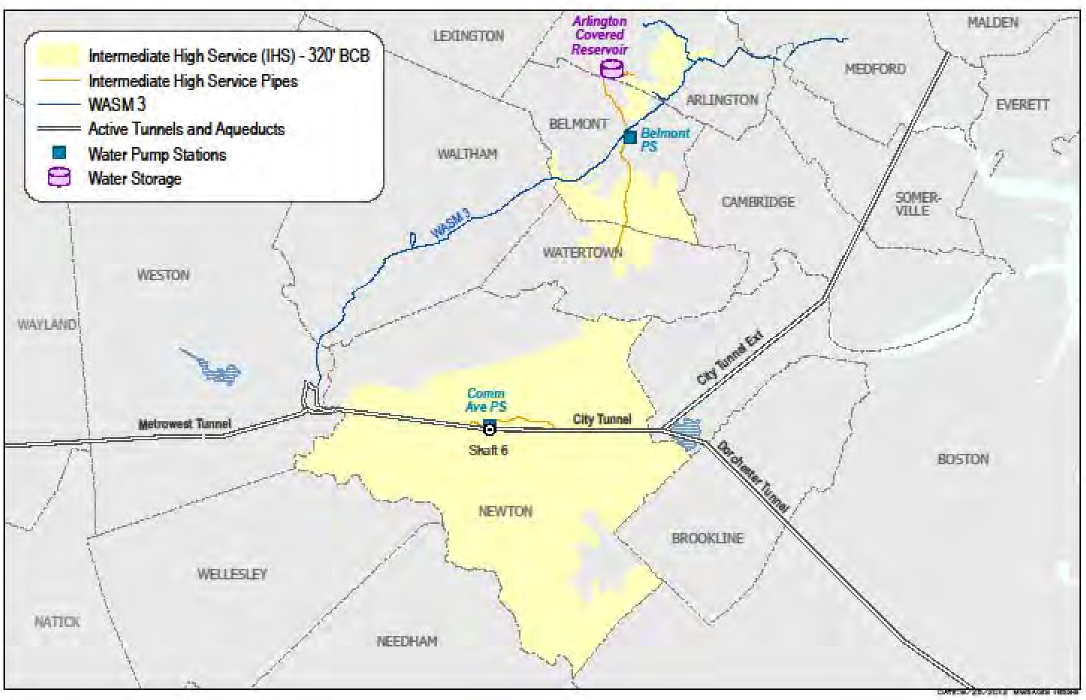
- The Fisher Hill Pipeline was initially proposed to be rehabilitated with the Walnut Street Pipeline but was removed from the CIP. This project involves the design and rehabilitation of approximately 3,200 linear feet of 36-inch pipe; 3570 linear feet of 30-inch pipe; and 1,190 linear feet of 42-inch cast iron mains. These mains are all in excess of 100 years old and have limited carrying capacity due to tuberculation with C-values in the 58-60 range. The estimated cost for construction of this project is $2.7 million and this work is proposed for the FY24-29 time period.

- Southern Spines Distribution Mains-Rehabilitation of Section 19. This project would include the design and construction of 13,000 linear feet of 48-inch main. Rehabilitation is expected to be cleaning lining and replacement of main line valves, blow-off valves and appurtenances. This project was previously dropped from the CIP due to budgetary concerns. However, Section 19 was constructed in the 1890's and has C-values in the 60's. The estimated cost for design and construction is approximately $8.1 million. This project is proposed to be started in the FY24-29 time period.

8.10 Intermediate High Service

The Intermediate High Service zone consists of two geographically distinct and hydraulically unconnected areas served at similar grade lines (elev. 320') approximately 50 feet higher than high service. The southern area is a portion of Newton lying south of the Massachusetts Turnpike supplied by the Commonwealth Ave. pumping station which takes suction from Shaft 6 of the City Tunnel and pumps to the City owned Newton Covered Storage Reservoir on Waban Hill. The second area is further north and consists of portions of three communities served by water from Norumbega Covered Storage Facility which is transported via WASM 3 and then pumped from the Belmont Pump Station to the Arlington Covered Reservoir (elev. 320'). The Intermediate High service area had a 2011 average day demand of 7.91MGD.

Figure 8-14



<u>Delivery System Condition and Ongoing Work</u>: The northern part of this area is served by a small diameter, single north/south pipe (Section 59) which is in poor condition with low C-values. From a redundancy standpoint, this system is vulnerable. MWRA staff installed a PRV in the vicinity of the Arlington Covered Reservoir which can provide

Northern Extra High water if the Belmont Pumping Station fails or needs to be taken out of service. The major vulnerability is the single pipeline service, and the fact that the covered storage is not at an optimal location. Section 75 serves the southern part of this zone. This is a concrete pipe approximately 60 years old.

The pipes in the Intermediate High system are generally unlined cast iron with C-values in the 70's. The replacement or rehabilitation of Sections 59 and 60 pipe remains as a subphase (~$5.9 million design and construction) of the Shaft 7 to WASM 3 connecting main project but because that project has undergoing redesign, the ability of the connecting mains to provide redundant service to this area while Sections 59 is being cleaned and lined is no longer possible. It is possible still to rehabilitate Section 60. Another subphase of the Connecting Mains project is the design and construction for the replacement of Section 25 which entails 4,800 linear feet of 16-inch diameter pipe at a projected design and construction cost of $3.2 million with construction to start in April 2018.

The Belmont pump station was part of the $29 million project to upgrade the five remaining older pump stations in the system. The Belmont station was built in 1937 and has occasionally been out of service for extended periods due to fire damage or the need to replace equipment. This rehabilitation included installation of new mechanical, electrical, instrumentation and security systems and also included building and site renewal.

An additional project recommended in the 2006 Water System Master Plan has been added to the CIP. This is the Section 75 Extension. Section 75 delivers water to the Newton Covered Reservoir (owned and operated by Newton) from the Commonwealth Ave. P.S. but Section 75 does not extend the full distance to the Reservoir with the last 6,000 feet being Newton pipe. A new 30-inch diameter pipe would permit Sections 23, 24 and 47 to be operated at the head of the Intermediate High system. In conjunction with the Section 25 replacement (noted above) it would permit the two geographically distinct areas to be connected and operated as one system. This project would also allow Section 59 to be taken out of service for rehabilitation. This eliminates the need to build a replacement pipeline for Section 59 which had been estimated to cost $10 million. This proposed project would have the additional benefit of increasing pressure to Boston Meter 120

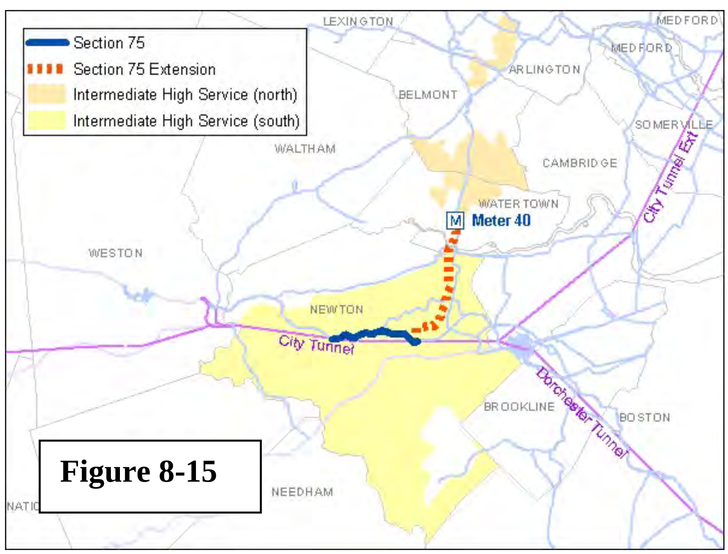


Figure 8-15

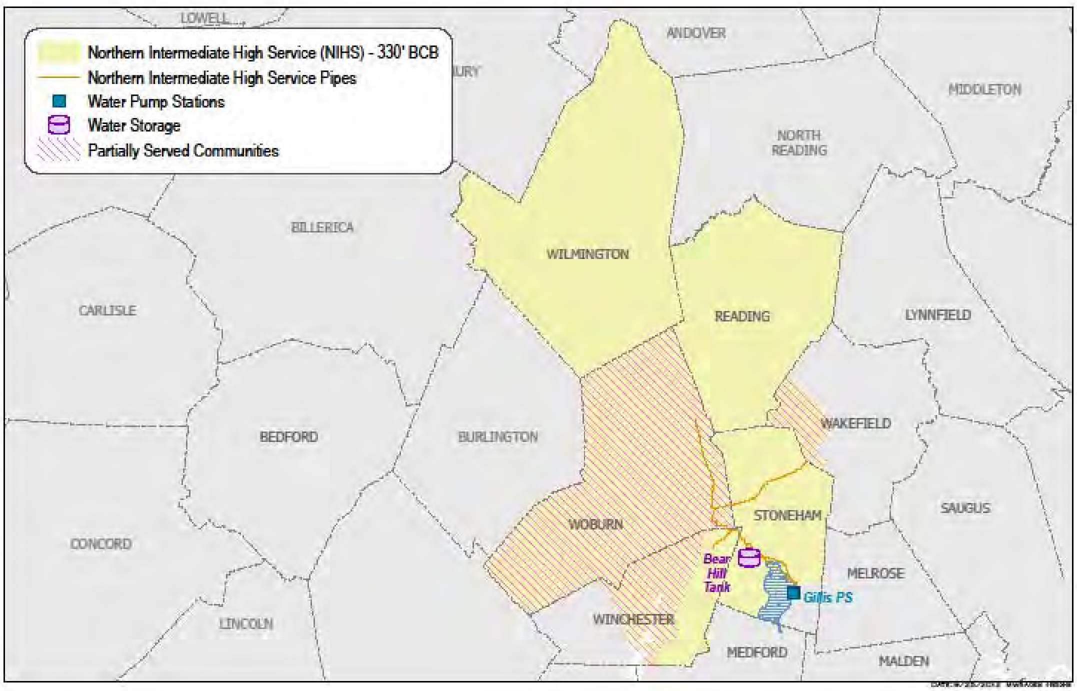
(Notting Hill area). This project has an estimated cost of $4.4 million and design is currently scheduled to begin in October of 2015 and take up to four years to complete.

No projects beyond those identified in the FY14 CIP are recommended at this time.

8.11 Northern Intermediate High Service

The Northern Intermediate High Service zone is one of the smaller pressure zones and was once considered part of the Northern High Service area. It is supplied by water pumped from the Gillis Pump Station to the Bear Hill Tank (elev. 330'). The Gillis Pump Station draws its supply from the Northern High via the 72-inch diameter Section 99. Water is distributed to 6 fully or partially supplied communities north of Spot Pond.

Figure 8-16



Delivery System Condition and Ongoing Work: From a redundancy standpoint, the NIH service area was identified in the 2006 Master Plan as an area lacking redundancy-the service area has a single supply point and a single tank which limits repair or maintenance opportunities as well as increasing the impact if a failure were to occur. Stoneham, in particular, has no local storage or other connections to rely on during a system problem. Concern over the potential for a catastrophic failure of Section 89 increased when in-house research showed that a 10,000 foot portion of this pipeline was a Prestressed Concrete Cylinder Pipe (PCCP) that was constructed by a particular manufacturer with a Class IV wire that has been prone to embrittlement and failure elsewhere in the country. Because of this, the NIH Assessment and Concept Plan was initiated to assess short-term risk reduction measures that might be undertaken to limit the effects of a pipe failure and develop conceptual level plans for the provision of a redundant pipe, a redundant pump station and additional storage. Concept Planning work was completed and a series of projects, both short and long-term have been added to the subsequent CIPs to reflect the Concept Plan's recommendations.

Example of a brittle wire failure

Pipelines: The one section of Section 89 that has redundancy is a small part underneath Spot Pond which is backed up by Section 29 north of the Pond. However, Section 29 is an old, unlined cast iron main which is severely corroded and has limited carrying capacity. Emergency repair parts for Section 89 have been purchased, and are kept at the Chelsea facility if needed.

Design of a redundant pipeline approximately seven miles in length, is now underway and construction is expected to be initiated in two phases, both beginning in 2015 with an estimated construction cost of approximately $43 million. At the point that construction of the new pipeline is underway, design for the rehabilitation of the existing pipelines will be initiated. Design and construction for the rehabilitation of these pipelines is carried in the FY14 CIP with a cost of approximately $8.8 million with design scheduled to begin in FY17.

Pump Stations: In addition, this service area is entirely dependent on the Gillis Pumping Station. The rehabilitation of this pumping station substantially improved the reliability of providing flow from the station to Bear Hill, however, the Concept Plan also recommended a redundant pump station to improve the flexibility and reliability of operations. The new pump station, which is being integrated into the design of the Spot Pond Storage project, will have similar operational capabilities as does Gillis pump station. Gillis currently supplies two service areas from the one station – five pumps are dedicated to the Northern Intermediate High (NIH) service area, and three pumps are dedicated to the Northern High Service/Fells (NHS/Fells) service area. The operation of the new station will be integrated into the day to day operation of Gillis to the NIH service area, similar to the operation of Hyde Park and Newton Street pump stations in the Southern Extra High (SEH) service area, and Brattle Court and Spring Street pump stations in the Northern Extra High (NEH) service area. The NIH pumps at Spot Pond and Gillis will be programmed to run in a lead/lag fashion to provide redundancy to the NIH that has been lacking.

Storage: The single storage facility, Bear Hill Tank, has a capacity of 6 MG and is located near Gillis Station. The Bear Hill tank was built in the 1980's and is in good physical condition but it is not able to be taken off-line for cleaning. Mechanical cleaning while the tank is in operation has been used but major rehabilitation work, if necessary, is not currently possible.

The 1993 *Water Distribution System Storage* study recommended placement of additional storage at the Bear Hill site. Given the shift in demand to the north, the Bear Hill site was no longer considered a preferable location compared to potential sites further to the north in the service area. The additional storage required continues to be estimated at 6 MG. Although the Concept Plan identified potential storage locations, MWRA has been unable to come to a final agreement on siting of storage. Discussions are ongoing and the FY14 CIP contains approximately $20 million for design and construction of storage.

Short-Term Measures for Risk Reduction:

The 2008 *NIH Assessment and Concept Plan on Short-Term Risk Reduction Strategies*, contained a number of recommendations to address risk reduction in the NIH service area for the time prior to a redundant pipeline and pump station being constructed. Community interconnections were identified as a significant way to facilitate the transfer of water in an emergency from communities both outside the MWRA service area and from other pressure zones within the MWRA service area. A number of interconnections were constructed and MWRA purchased a Mobile Pumping Unit that meets the necessary specifications in the event of a NIH pipeline failure (and available to be used for other emergency needs). The plan also recommends that variable frequency drives (VFDs) replace the constant speed motors on two pumps. This will allow the pumps to operate over a much larger flow and head range further increasing the operational flexibility of the Gillis Station.

Section 89 Globe Valve Replacement: Section 89 is the primary discharge main from the Gillis pump station to the NIH system. At its northernmost point, it crosses Route 128/I-95 at Washington Street in Woburn over the highway on a pipe bridge. Mass DOT required the installation of “line break” valves on either side of the bridge when it was constructed in the mid 1980’s to minimize the potential of large volumes of water escaping onto the highway due to a catastrophic failure of the pipe. Section 89 at this crossing is a 36” main; the line break valves on either side of the bridge are 24” globe body style valves. The valves are set to close if the pressure in the line gets to a low, pre-set pressure, significantly lower than the operating pressure in the line. The original water supply customer at the northern end of Section 89 in Woburn was the city of Woburn, at Meter 230. Now, both Reading (Meter 240) and Wilmington (Meter 339) are MWRA customers, with their respective meters co-located with Meter 230 to Woburn. Reading is being supplied with 100% of their water thru Meter 240; Wilmington is a partially supplied community thru Meter 339. During the peak flow periods on summer days, the demand thru the three meters can exceed 10 to 12 mgd. This high flow rate thru the two 24" globe body valves creates a high enough head loss to drop the hydraulic grade line at the three meters to unacceptable levels. In addition, the small diameter piping to Meter 240 (Reading) causes additional head loss.

A plan was developed to deal with the head loss reduction in the interim time prior to the construction of the redundant NIH pipeline. Hydraulic modeling of the improvements was completed to confirm the hydraulic benefits of the proposed improvements. Each of the three meters have check valves that will prevent water from flowing back towards the pipe bridge in the event of a catastrophic failure. The existence of the check valves allowed for the removal of the northern 24" globe valve, and its replacement with a straight piece of 36" pipe. This was completed in the spring of 2012, prior to the start of summer demand. The 12" diameter piping to Meter 240 noted above had been tapped during its original construction for the installation of the 12" meter piping to Meter 339, which induced additional head loss. A new direct tap on the 36" Section 89 piping was performed in the spring of 2012, with additional 12" piping installed for a direct connection from Section 89 to Meter 339, reducing the head loss to Meter 240. The third phase of the interim improvements was completed with the removal of the southern 24" globe valve and the installation of a new 36"(full pipeline diameter) globe valve. This work will reduce the head loss in the northern portion of Section 89 until the redundant pipeline is constructed. When the redundant pipeline is constructed, a full diameter line break valve will be reinstalled on the north side of the pipe bridge.

The graphics below show the location of the work that has been completed to date and the photos show the removal of the northern globe valve and the replacement piece of straight pipe that was installed. No projects beyond those identified in the FY14 CIP are recommended at this time.


230/Woburn
240/Reading
339/Wilmington
89-62-C
Section 89
89-62-B
Automatic Isolation Valves
Meters
Distribution Pipes

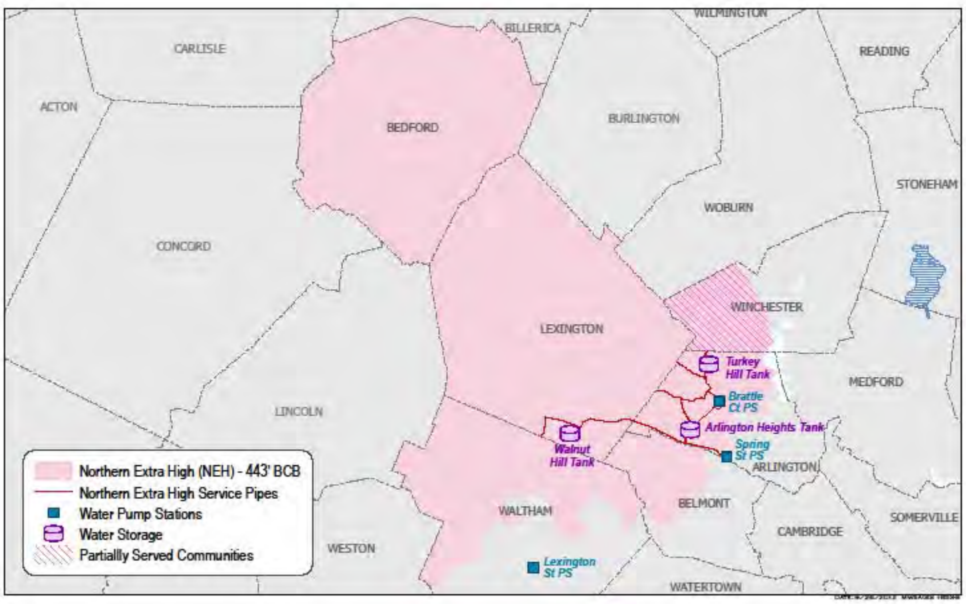

04/11/2012


04/11/2012

8.12 Northern Extra High Service

The Northern Extra High zone provides water to the highest gradelines in the system. Six suburban communities in the hilly region northwest of the Boston are supplied by water from the Norumbega Reservoir via WASM 3 which is pumped to three MWRA owned tanks and one community owned tank. The elevations of the MWRA tanks range from 442' to 445'. The Brattle Court and Spring Street Pumping Stations discharge directly into the Northern Extra High while the Lexington Street Pumping Station discharges directly into Waltham's Prospect Hill service area.

Figure 8-17



<u>Delivery System Condition and Ongoing Work</u>**:** Sections 34, 36, 45, 63 and 83 provide service to this system. As was noted in 1993, the original pipelines were not large enough to meet maximum day demands plus fire flow service goals. To address this issue, Section 45, a 16-inch diameter pipe installed in 1920 was partially rehabilitated but 2,600 linear feet remain to be done. Approximately 3,400 linear feet of Section 63 was rehabilitated and Section 83 was reinforced with a parallel main. The remaining work will address Sections 34 and 36 and the last 2,600 linear feet of Section 45. Section 34 is an undersized (12-inch) unlined cast iron main (built in 1911) and may be the source of localized water quality problems. This line is required to provide service between the Brattle Court Pump Station and the distribution system. Section 36, also constructed in 1911 is just under a mile in length is also undersized at 16-inches and this main is part of the Brattle Court discharge piping. Currently, Section 36 is highly tuberculated and has

limited flow. It is currently not adequate to maintain an acceptable hydraulic grade line at the Walnut Hill Tank and at the Lexington and Waltham meters. Section 36 work includes replacement of approximately 4,500 linear feet of 16-inch diameter pipeline with new 24-inch diameter pipeline and appurtenances in the same trench along public and private rads in Arlington. Replacement of this pipeline will improve the NEH hydraulics and enable the Spring Street Pump Station and the Brattle Court Pump Station to be redundant to each other. Currently, the Brattle Court Pump Station piping is not sufficient to provide adequate service to the Spring Street service area in an emergency. This should result in better fire protection and reduced pumping costs. Design is ongoing and construction is scheduled to start in FY15.

The Lexington Street Pumping Station was rehabilitated in the 1990's and the Brattle Court Pumping Station and Spring Street Pumping Stations are scheduled for rehabilitation beginning in FY07. This work includes new mechanical, electrical, instrumentation and security systems as well as building and site renewal. SCADA installation at all stations was completed under a fast track contract in 2001.

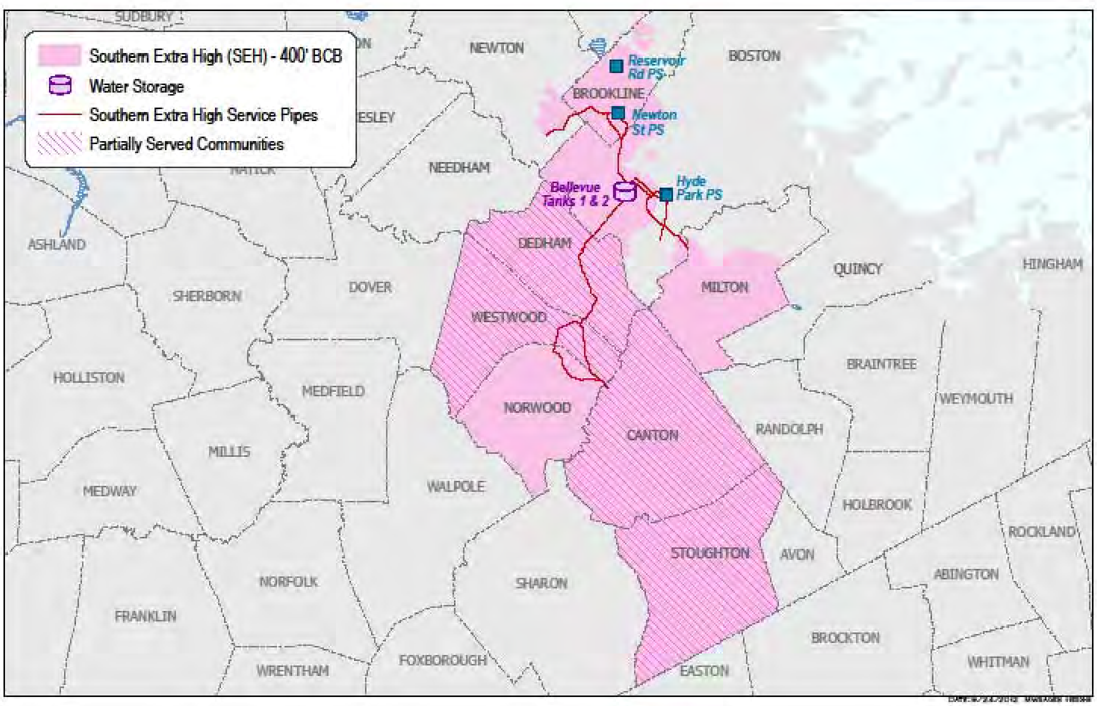
The storage tanks in the service area vary from the old Arlington Heights Standpipe to the more recently constructed Walnut Hill and Turkey Hill tanks. Tank location also prevents good circulation of water in Arlington Heights. Current inspection and maintenance programs are meeting needs in this area and no major expenditures are anticipated.

The 2006 Water System Master Plan recommended rehabilitation of the Section 83 Dropholes. Although it does not affect capacity, Section 83 was constructed to specification that required an additional metal fitting inserted into the top of the pipe (dropholes) along the 4-5 mile length. These have a tendency to fail and result in leakage and require frequent maintenance. A design and construction contract to eliminate these dropholes (using vacuum excavations to locate them) was recommended in 2006. However, since 2006, there have not been any recurring issues. It is now recommended that this situation continue to be monitored and if maintenance needs increase, consideration again be given to developing and implementing a project to address this pipe.

8.13 Southern Extra High Service

The Southern Extra High zone includes the Roslindale and West Roxbury sections of Boston, a portion of Brookline and six suburban communities to the south of Boston. This zone is supplied by water from Norumbega Covered Storage to the Southern High Mains via the City Tunnel and the Dorchester Tunnel. The Southern High Mains provide the suction for three pumping stations: Hyde Park, Newton Street and Reservoir Road. Hyde Park and Newton Street Pump Stations pump to the Bellevue standpipe No. 2 while Reservoir Road Pump Station pumps to the Singletree Tank owned by the Town of Brookline. In the event of a power failure or some other service disruption that takes Reservoir Road out of service, there is a PRV that opens automatically at the Newton St. Pump Station to supply the Singletree service area. The SEH service area has grown in the past several years with the addition of the partially supplied Town of Stoughton and the Dedham-Westwood Water District. As discussed below, this further exacerbates concerns about the lack of redundancy and limited storage in this pressure zone.

Figure 8-18



Delivery System Condition and Ongoing Work: Lack of redundancy is the major issue within the SEH system. Sections 77 and 88 are single spine mains serving Canton, Norwood, the Dedham-Westwood Water District and Stoughton. Although four of these communities are partially supplied and may be able, in part, to provide some level of service in the event of a pipeline leak, break or other failure, Norwood is fully supplied by MWRA.

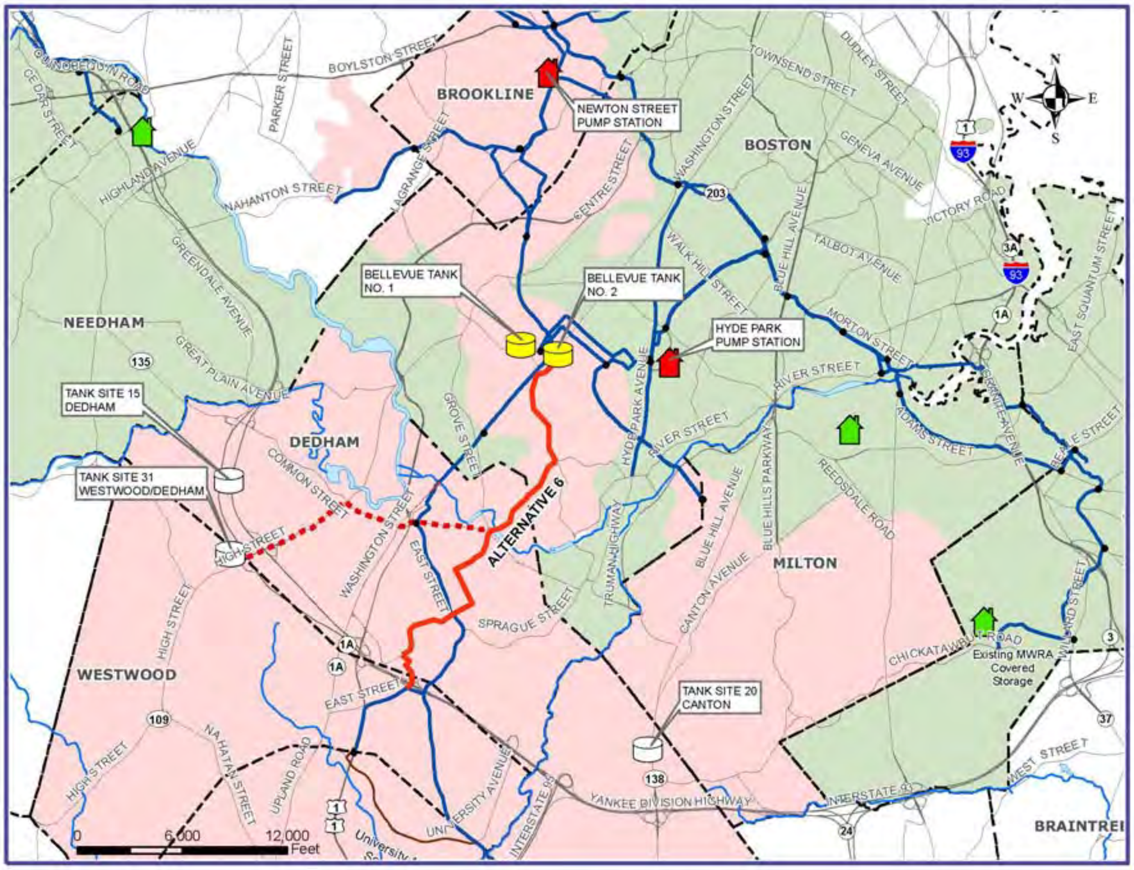
The Bellevue tanks consist of a newer 3.7 million gallon tank having a 400' elevation and an older 2.5 million gallon tank having a 375' elevation. The older tank stagnates since it cannot contribute unless there is a 25 foot drawdown on the higher tank. It has been valved off due to concerns that the stagnant water may accidentally be drawn back into service. There is a plan to use a recirculation unit to better maintain water quality within the older tank.

The volume of storage in the SEH is small in proportion to demand such that there is little storage dampening on a summer day. In past summers, there have been 35' fluctuations in tank levels over the course of a peak day. In addition, like the NIH system, the SEH service area has geographically expanded and the growth has been concentrated to the south meaning that the existing Bellevue tanks are at the upper periphery of the service area. Additional storage to the south (closer to the center of demand) would be of great benefit.

At the November 2006 Board of Directors meeting, the Board approved inclusion of $900,000 in the CIP for development of a Concept Plan for the Southern Extra High service area. This study has now been completed and projects added to MWRA's capital budget to address the service area deficiencies. Prior to the completion of the Concept Plan, a short term measure to link Sections 77 and 88 together along University Avenue in Norwood was completed in 2008 as an immediate way to reduce the level of risk in the service area. Longer term projects are discussed and illustrated, in part, by Figure 8-X below.

Figure 8-19 shows the currently proposed redundancy project for the SEH service area. This provides an alternative to flow coming through Section 77. MEPA review was completed in 2013 and the design contract has been approved by the Board of Directors. Construction is expected to start in 2016. Future project phases will extend through 2037 and will address the continued need for storage in the SEH service area and the map shows locations identified in the Concept Plan. The funds for these future stages have been incorporated into MWRA's CIP. In addition, rehabilitation of the existing Sections 77 and 88 are included in the CIP to be done in the FY23-25 time period at an estimated design and construction cost of approximately $6.5 million.

Figure 8-19



Other pipes in the service area are typically smaller diameter and not as old as in some other parts of the system. Sections 41 and 42 are unlined cast iron 20-inch pipe built in 1914 and Section 74 was built in 1951 of PCCP. These mains connect the Hyde Park Pump Station and the Newton Street Pump Station discharge pipeline (Section 77) to Bellevue Tanks 1 and 2. These pipes were initially installed prior to the construction of Bellevue 2 which is 25 feet higher than Bellevue 1. Thus, these pipes were not designed to withstand the higher pressures associated with the use of Tank 2 and the result was that the Pump Station could not be operated at full capacity without limiting the volume of water in Tank 2 which subsequently led to problems in meeting peak demands. To fix this, construction was completed in 2003 to replace Sections 41 and 42 with 8,000 feet of new 24-inch diameter pipe and to a portion of Section 74 with about 2,700 feet of new 24-inch diameter pipe. An additional 6,400 feet of Section 74 was rehabilitated.

The remaining small diameter unlined cast iron mains (Sections 30, 40, 44 and 39) range in age from 97 to 104 years old (with a small part of Section 44 only 49 years old). Sections 30 and 44 serve Boston and Milton. Section 39 provides suction to the Hyde Park Pump Station. These lines are tuberculated and have low C-values. Meters 55 and 68 are served by a single line and all of Milton cannot be fed off of Meter 55 due to tuberculation. Milton is installing a PRV to allow the Town's low service system to be fed off of the high system in the event that it is necessary. A parallel main would improve service to the meters.

Newton Street was one of the pumping stations included in the initial round of upgrades in the 1990's. Reservoir Road and Hyde Park Pumping Stations (built in 1936 and 1912 respectively) were included in the upgrade project completed since 2006. All major building systems were replaced and building and site refurbishment was done.

Recommended Projects: Southern Extra High

- Design and Construction for Sections 30, 40, 44 and 39. The design and construction costs are estimated to be $10 million in the FY34-39 time period.

- A parallel line to serve meters 55 and 68 in Milton should be considered in conjunction with the above project. The estimated cost is $5 million in the FY30-33 time period.

8.14 Summary of Recommended Metropolitan System Improvements

- Two additional phases of valve replacement (Phases 10 and 11) are recommended at a cost of $9 million with a start date of FY 24. In order to continue to increase the percentage of operable valves and to address valves that fail during the next 40 year period, work will need to continue using both the current CIP project and in-house design services. In addition, it is expected to take additional time to complete the blow off valve retrofit program. The mix of in-house and CIP work on all phases of the MWRA valves has been the key to operational success of the system.

- Staff should also continue to monitor the maintenance needs for the butterfly valves that have replaced gate valves in various parts of the system. Gate valves have routinely had an expected life in the MWRA system of 50-75 years and there is some concern that the butterfly valves may not be as resilient and more prone to breakage and misalignment. For the next master plan update, review this information and complete a revised life cycle cost analysis if appropriate.

- It is recommended that $2.4 million be added to a future CIP for evaluation and rehabilitation of mechanical and other equipment as necessary for the Blue Hills facility in the FY29-31 time period. Similar maintenance work will be identified in the next Master Planning cycle for the Spot Pond Covered Storage facility once it has come on line.

- Staff recommends that an additional $25 million be added to the CIP in the FY34-43 time period for the next cycle of pump station rehabilitation for those stations completed in 2010. This would include replacement of instrumentation, electrical and mechanical systems at the pump stations.

- Staff recommends that a pipeline study be done at a cost of up to $500,000 to assess long-term pipeline renewal needs based on MWRA specific information. The Master Plan proposes that this work be done in FY20.

- Given the greater than one billion dollars anticipated to be needed for future community water main replacement/rehabilitation cost, staff recommend continues systematic investment in local water system infrastructure through MWRA financial assistance. For master planning purposes, staff recommend future third and fourth phases of the Local Water System Assistance Program be considered for funding in future CIPs. Each new phase is recommended to provide $210 million in interest-free loans (with 10-year loan repayments) during the FY21-40 and FY31-50 time periods. Because loan distributions are offset by community repayments over time, the net CIP budget of each recommended loan phase is zero. Prior to expansion of the current program, coordination with the MWRA Advisory Board is required to develop a recommendation for Board of Directors consideration.

- Design and Construction for replacement and rehabilitation of 5,000 linear feet of 36-inch pipe on Section 66 and replacement and rehabilitation of 5,000 linear feet of 30-inch pipe with 36-inch pipe on Old Mystic Main. Abandonment of 14,000 linear feet of 150 year old 24-inch cast iron main. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $8.2 million and, in conjunction with the project below, should be scheduled in the FY24-33 time period.

- Design and Construction for rehabilitation of the remaining portion of Section 57 in Riverside Avenue (approximately 8,000 linear feet) in Medford along with rehabilitation of the portion of Section 20 of the Metropolitan Sewer which is in the immediate proximity. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $21.4 million and this work should also be done in the FY24-33 time period.

- Rehabilitation of Section 56 which is currently isolated at the General Edwards Bridge due to excessive leaks. This is a 30-inch unlined steel pipe approximately 75 years old. This project was previously grouped in the project below (rehabilitation of the coastline mains) as part of elimination of old unlined pipe. However, due to Section 26 being out of service, it is recommended that design of Section 56 move forward as soon as possible to ensure a level of continued redundancy to the North Shore communities if there are failures in any of Sections 91, 87 or 72. The cost estimate for this work is $10 million and it is recommended that design work begin in July 2015. Given site constraints, it is assumed that directional drilling should be considered as a construction option.

- Pipeline rehabilitation of the small diameter unlined cast iron along the coastline from East Boston north to Lynn. This includes Sections 54, 55, and 69. Although these cast iron pipes are not as old as some of the other pipes in this service area (1932 and 1951 for Section 69), the C-values associated with these pipelines are estimated to range from 67-73 indicating that the 20-24-inch mains are severely corroded. The cost of this work is estimated to be $16.3 million. This is recommended for the FY20-25 time period.

- Pipeline rehabilitation of NHS Sections 13-18 and 48-unlined cast iron (except Section 48 which is unlined steel) with identified hydraulic restrictions. Sections 13-18 were generally constructed in the 1896-1903 time period and have C-values estimated to be as low as 57 along much of the area but ranging higher in other areas. Based on the analyses completed to rank pipelines, portions of Sections 14, 15, 17 and 18 were all in the top twenty of worst ranked sections. During design, the mix of cleaning and lining versus replacement of any seriously deteriorated segments can be determined. Section 48 is 30-38-inch diameter steel pipe constructed in 1930 with C-values of approximately 75. The estimated cost for design and construction is $18.4 million. This work is recommended for the FY29-33 time period.

- Pipeline rehabilitation of NHS Sections 33, 49, 49A, 50 in Revere and Malden at a cost of approximately $8 million. These are smaller diameter unlined cast iron mains ranging in age from 85 to over 100 years old in age and with C-values in the 60-70 range. Based on historical leak information and C-value, portions of Section 33 ranked in the top ten worst pipe segments in the analyses completed. This work is recommended for the FY 29-33 time period.

- Rehabilitation of the major unlined steel mains that serve the Northern High. This includes NHS Sections 70 and 71 and 79 which consists of more than 10 miles of corroded pipeline in Stoneham, Saugus, Melrose and Lynn. Design and construction for rehabilitation of these mains could extend over a 10-20 year period and will need to be carefully phased. Moving forward with rehabilitation is expected to extend the life of the pipe and postpone need for more costly pipe replacement. The CIP currently contains a planning study at a cost of $1 million to evaluate the appropriate sequencing of work prior to proceeding with rehabilitation. It is possible that such a study could be completed in-house if staff resources are available. The estimated design and construction costs for the rehabilitation work is $35.7 million and should be initiated in the FY 30-36 time period.

- The Fisher Hill Pipeline was initially proposed to be rehabilitated with the Walnut Street Pipeline but was removed from the CIP. This project involves the design and rehabilitation of approximately 3,200 linear feet of 36-inch pipe; 3570 linear feet of 30-inch pipe; and 1,190 linear feet of 42-inch cast iron mains. These mains are all in excess of 100 years old and have limited carrying capacity due to tuberculation with C-values in the 58-60 range. The estimated cost for construction of this project is $2.7 million and this work is proposed for the FY24-29 time period.

- Southern Spines Distribution Mains-Rehabilitation of Section 19. This project would include the design and construction of 13,000 linear feet of 48-inch main. Rehabilitation is expected to be cleaning lining and replacement of main line valves, blow-off valves and appurtenances. This project was previously dropped from the CIP due to budgetary concerns. However, Section 19 was constructed in the 1890’s and has C-values in the 60’s. The estimated cost for design and construction is approximately $8.1 million. This project is proposed to be started in the FY24-29 time period.

- Section 75 Extension-Section 75 delivers water to the Newton Covered Reservoir (owned and operated by Newton) from the Commonwealth Ave. P.S. but Section 75 does not extend the full distance to the Reservoir with the last 6,000 feet being Newton pipe. A new 30-inch diameter pipe would permit Sections 23, 24 and 47 to be operated at the head of the Intermediate High system. In conjunction with the Section 25 replacement (noted above) it would permit the two geographically distinct areas to be connected and operated as one system. This project would also allow Section 59 to be taken out of service for rehabilitation. This eliminates the need to build a replacement pipeline for Section 59 which had been estimated to cost $10 million. This proposed project would have the additional benefit of increasing pressure to Boston Meter 120 (Notting Hill area). This project has an estimated cost of $4.4 million and should be completed in the FY13-16 time period.

- Design and Construction for Sections 30, 40, 44 and 39. The design and construction costs are estimated to be $10 million in the FY34-39 time period.

- A parallel line to serve meters 55 and 68 in Milton should be considered in conjunction with the above project. The estimated cost is $5 million. In the FY30-33 time period.

Table 8-8

Water System Master Plan - Community-Owned Systems/Community Support

Existing and Recommended Projects

Last revision 9/30/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
		COMMUNITY-OWNED SYSTEMS/COMMUNITY SUPPORT - WATER											
8.01	3	Phase 1 - Local Pipeline Assistance Program (Net Cost-Repayments Only)	AP	765	multi	10 years	(87,000)	ongoing-FY23	(63,000)	(24,000)	0	0	(87,000)
8.02	3	Phase 2 - Local Water System Assistance Program (Net Cost-Loans and Repayments)	AP	765	multi	17 years	(31,000)	ongoing-FY30	66,000	(26,000)	(71,000)	0	(31,000)
		SUBTOTAL - Existing - Community Support					**(118,000)**		**3,000**	**(50,000)**	**(71,000)**	**0**	**(118,000)**
8.03	3	Phase 3 - Local Water System Assistance Program ($210 million interest-free loans)	AP	new		20 years	0	FY21-40		54,000	9,000	(63,000)	0
8.04	3	Phase 4 - Local Water System Assistance Program ($210 million interest-free loans)	AP	new		20 years	0	FY31-50			54,000	(54,000)	0
		SUBTOTAL - Recommended - Community Support					**0**		**0**	**54,000**	**63,000**	**(117,000)**	**0**
		SUBTOTAL - Existing and Recommended - Community Support					**(118,000)**		**3,000**	**4,000**	**(8,000)**	**(117,000)**	**(118,000)**

Table 8-9

Water Master Plan - Metropolitan System

Existing and Recommended Projects

Last revision 9/30/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF New Facility/System
RF/IC Replacement Facility/Increase Capacity
Opti Optimization
AP Asset Protection
Plan Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
		METROPOLITAN SYSTEM											
8.01	2	Northern High NW Transmission Section 70 - Planning	Plan/AP	618	60063_6895	2 years	1,000	FY16-17	1,000				1,000
8.02	2	Valve Replacement - Valve 8 and 9 - Design and Construction and Equipment Purchase	AP	677	68330_7417 68331_7418 68300_7195 68307_7236 68005_6088	8 years	10,295	FY16-23	3,131	7,164			10,295
8.03	3	Northern High Service - Section 27 Improvements - Construction	AP	692	67769_6333	3 years	892	FY18-20	150	742			892
8.04	3	Northern High Service Revere and Malden Pipeline Improvements, Sections 68 & 53A - Design and Construction	AP	693	75526_7402 67790_6335	5 years	8,282	FY15-19	8,132	150			8,282
8.05	3	Northern High Service Shaft 9A-D Extension - Design and Construction	NFOpti	693	75527_7403 68258_6958	5 years	3,472	FY17-21	214	3,258			3,472
8.06	3	New Connecting Mains Shaft 7 - WASM 3 CP3 - Design and Construction	AP	702	68112_6385 68119_6392	6 years	8,781	FY17-22	5,619	3,162			8,781
8.07	3	New Connecting Mains Shaft 7 - WASM 3 CP2 - Sections 59 & 60 - Design and Construction	AP	702	68286_7086 68174_6548	5 years	5,931	FY16-20	1,753	4,178			5,931
8.08	3	New Connecting Mains Shaft 7 - WASM 3 - Replacement of Section 25 - Design and Construction	AP	702	68255_6955 68256_6956	6 years	3,199	FY16-21	759	2,440			3,199
8.09	2	New Connecting Mains Shaft 5 - WASM 3 - Section 75 Extension - Construction	NF/R	702	68315_7284	5 years	4,400	FY16-20	2,640	1,760			4,400
8.10	3	Northern Extra High Service - Section 34 & 45 - Design and Construction	AP	708	75528_7404 68162_6522	6 years	3,960	FY16-21	1,145	2,815			3,960
8.11	3	Cathodic Protection of Distribution Mains - Test Station Installation 2, 3 and 4	AP	712	68129_6438 68130_6439 68131_6440	8 years	1,450	FY15-22	725	725			1,450
8.12	3	Spot Pond Supply Mains Rehabilitation - Section 4 Design and Construction	AP	713	60114_7334 60115_7335	5 years	2,000	FY14-18	2,000				2,000
8.13	3	Spot Pond Supply Mains Rehabilitation - Section 50 Design and Construction	AP	713	60116_7336 60117_7337	4 years	2,000	FY17-20	250	1,750			2,000
8.14	3	Spot Pond Supply Mains Rehablitation - Construction 4 - Bridge Trusses	AP	713	68209_6697	3 years	1,263	FY17-19	725	538			1,263
8.15	1	Chestnut Hill Connecting Mains - Shaft 7 Building- Design and Construction	NF	719	68052_6302	5 years	5,628	FY22-26		351	5,277		5,628
8.16	2	Chestnut Hill Emergency Pump Station - Emergency Generation - Design and Construction	NF	719	68268_6995 68267_6982	6 years	8,187	FY17-21	837	7,350			8,187

Table 8-9

Water Master Plan - Metropolitan System

Existing and Recommended Projects

Last revision 9/30/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF New Facility/System
RF/IC Replacement Facility/Increase Capacity
Opti Optimization
AP Asset Protection
Plan Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
		METROPOLITAN SYSTEM											
8.17	3	Southern Spine Distribution Mains - Section 20 and 58 - Design and Construction	AP	721	68089_6296 68091_6298	6 years	16,351	FY23-28		434	15,917		16,351
8.18	1	Southern Spine Distribution Mains - Section 22 North - Planning/Design/Construction	AP	721	68299_7155 68298_7120 68235_6844	9 years	19,958	FY17-25	875	11,679	7,404		19,958
8.19	1	Northern Intermediate High Redundancy - Design and Construction (Phases 1 and 2)	NF/R	722	68252_6906 68282_7066 68283_7067	6 years	46,706	ongoing-FY19	37,999	8,707			46,706
8.20	1	Northern Intermediate High Section 89 and 29 Rehabilitation - Design and Construction	AP	722	68294_7116 68295_7117	6 years	8,766	FY18-23	285	8,481			8,766
8.21	1	Northern Intermediate High Storage - Design and Construction	NF/R	722	68316_7311 68284_7068	6 years	20,815	FY17-22	1,254	19,561			20,815
8.22		Northern Intermediate High - Short Term Improvements - Design	AP	722	68277_7045	2 years	200	ongoing-FY15	200				200
8.23		Gillis Pump Station Improvements	AP	722	68309_7260	1 year	2,020	FY14	2,020				2,020
8.24	3	Northern Low Service Rehabilitation Section 8 - Design and Construction	AP	723	68287_7092 68095_6322	6 years	16,095	FY18-23	300	15,795			16,095
8.25	3	Northern Low Service Rehabilitation Sections 37 & 46 - Design and Construction	AP	723	75529_7405 68262_6962	4 years	3,930	FY17-20	400	3,530			3,930
8.26	2	Southern Extra High Redundancy and Storage - Phase 1 - Design and Construction	NF/R	727	53398_6453 53399_6454	7 years	33,978	FY14-20	26,161	7,817			33,978
8.27	2	Southern Extra High Redundancy and Storage - Phase 2 - Design and Construction	NF/R	727	68135_6444 68308_7245	7 years	33,807	FY26-32			33,807		33,807
8.28	2	Southern Extra High Redundancy and Storage Sections 77 and 88 Rehabilitation - Design and Construction	AP	727	68292_7112 68293_7113	6 years	6,486	FY21-26		649	5,837		6,486
8.29	2	Southern Extra High Redundance and Storage - Phase 3 Design and Construction	NF/R	727	68312_7263 68311_7262	7 years	11,906	FY31-37			2,000	9,906	11,906
8.30	1	Weston Aqueduct Supply Mains - WASM 3 - Design and Construction	AP/R	730	68166_6539 68170_6543 68171_6544 68172_6545	12 years	195,977	FY14-25	23,702	153,635	18,640		195,977
8.31	1	Weston Aqueduct Supply Mains - Section 36 Design and Construction	AP/Opti	730	68167_6540 68332_7448	5 years	10,353	ongoing-FY17	10,353				10,353
8.32	2	Watertown Section Rehabilitation	AP	730	68301_7222	1 year	2,581	FY14	2,581				2,581
8.33	1	Section 101 Construction	NF/R	730	68333_7457	3 years	11,595	FY15-17	11,595				11,595
8.34	3	Section 80 Rehabilitation - Design and Construction	AP	735	68250_6892 68249_6891	6 years	9,340	FY17-22	636	8,704			9,340
8.35	3	Rehabilitation of Other Pump Stations - Pump Station Rehabilitation - Design and Construction	AP	704	75522_7383	5 years	25,000	FY20-24		15,073	9,927		25,000
8.36	2	Spot Pond Storage Facility - Design/Build	NF/R	550	53402_6457	2 years	28,434	ongoing-FY15	28,434				28,434
8.37	2	Spot Pond Storage Facility - Owner's Representative	NF/R	550	53462_7233	3 years	1,624	ongoing-FY16	1,624				1,624

Table 8-9
Water Master Plan - Metropolitan System
Existing and Recommended Projects

Last revision 9/30/13

Prioritization

1 Critical
2 Essential
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4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
		METROPOLITAN SYSTEM											
8.38	3	Waterworks Facilities Asset Protection - Walnut Hill Tank - Design and Construction	AP	766	75497_6832 75498_6833	5 years	1,300	FY16-20	996	304			1,300
8.39	3	Waterworks Facilities Asset Protection - Elevated Water Storage Tank Repainting	AP	766	75523_7384	4 years	5,000	FY16-19	4,584	416			5,000
8.40	2	Beacon Street Line Repair	AP	766	75537_7458	1 year	1,000	FY15	1,000				1,000
8.41	3	Waterworks Facilities Asset Protection - Covered Storage Tank Rehabilitation	AP	766	75524_7385	5 years	5,000	FY20-24		4,135	865		5,000
8.42	2	Section 56 Replacement - Saugus	AP	693	75545_7454	5 years	10,000	FY16-20	4,240	5,760			10,000
		SUBTOTAL - Existing - Metropolitan System					**598,962**		**188,319**	**301,063**	**99,674**	**9,906**	**598,962**
8.43	3	Section 66 - Old Mystic Main - Design and Construction	AP	new		5 years	8,200	FY24-29			8,200		8,200
8.44	3	Section 57 Design & Construction	AP	new		5 years	21,400	FY24-29			21,400		21,400
8.45	3	Rehabilitation of Coastline Pipelines (Sections 54, 55, and 69) D &C	AP	new		6 years	16,300	FY20-25		10,000	6,300		16,300
8.46	3	Northern High Service - Rehabilitation of Sections 13-18 and 48	AP	new		5 years	18,400	FY29-33			18,400		18,400
8.47	3	Northern High Service - Rehabilitation of Sections 33, 49, 49A and 50	AP	new		5 years	8,000	FY29-33			8,000		8,000
8.48	3	Northern High Service - Rehabilitation of Sections 70, 71 and 79	AP	new		6 years	35,700	FY30-36			20,000	15,700	35,700
8.49	3	Fisher Hill Pipeline Rehabiltation	AP	new		5 years	2,700	FY24-29			2,700		2,700
8.50	3	Southern Spine - Rehabilitation of Section 19	AP	new		5 years	8,100	FY24-29			8,100		8,100
8.51	3	Southern Extra High - Rehabilitation of Sections 30, 39, 40 and 44	AP	new		5 years	10,000	FY34-39				10,000	10,000
8.52	4	Parallel Line to Meters 55 and 68	NF/R	new		4 years	5,000	FY30-33			5,000		5,000
8.53	3	Pipeline Study	AP/Plan	new		1 year	500	FY20		500			500
8.54	3	Pump Station Rehabilitation - Phase 2	AP	new		10 years	25,000	FY34-43				25,000	25,000
8.55	3	Covered Storage-Blue Hills	AP	new		3 years	2,400	FY29-31			2,400		2,400
8.56	3	Valve Replacement - Phases 10 & 11	AP	new		ongoing	9,000	FY24-53			3,000	6,000	9,000
		SUBTOTAL - Recommended - Metropolitan System					**170,700**		**0**	**10,500**	**103,500**	**56,700**	**170,700**
		SUBTOTAL - Existing and Recommended - Metropolitan System					**769,662**		**188,319**	**311,563**	**203,174**	**66,606**	**769,662**

9 Ancillary Services

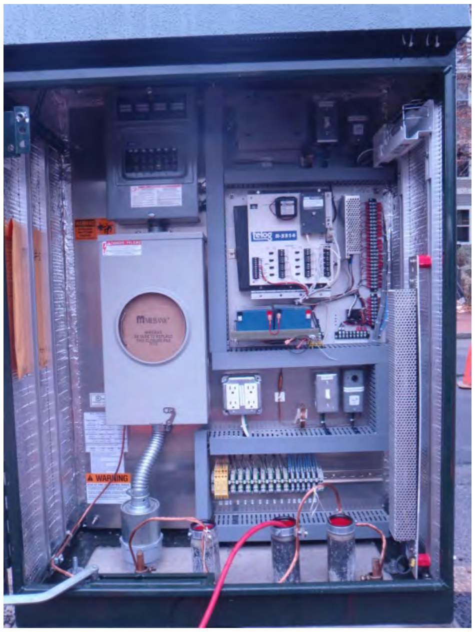
9.1 Chapter Summary

The operation and maintenance of the water supply and wastewater systems are supported by an array of processes, systems, and equipment. As an example these include metering equipment for flow measurement, telecommunications to monitor remote facilities, informational maps and records for locating existing underground mains and documenting changes to the system, laboratories for performing water quality tests and upgrades to equipment and facilities to address security needs. This chapter includes five specific support areas 1) Metering; 2) SCADA; 3) Laboratory Services; 4) Information Management; and, 5) Security. The first two areas (Metering and SCADA) are specific to the MWRA's water system. The latter three support functions apply to both the water and the wastewater systems and the discussions and recommendations for these functions (Laboratory Services, Information Management and Security) are also included in the 2012 Wastewater System Master Plan (see Chapter 13). The current conditions and needs of each functional group are discussed below along with corresponding recommendations for each group. Detail on wastewater SCADA and the wastewater metering system are provided in Chapter 12 of the Wastewater Master Plan.

9.2 Metering

There are essentially two kinds of meters, master meters and revenue meters. The approximately 68 master meters measure flow at key locations within the water transmission and distribution systems. Approximately 1/3 of these meters are tested every year with the entire system being tested within three years to ensure they are working properly. Water revenue meters measure delivered flow to the communities. There are between 160 and 180 water revenue meters. Each meter is comprised of a primary and secondary system. The primary flow device is the venturi tube. The secondary devices are the transmitters, above ground cabinet, data loggers and communications. As a general rule of thumb, the venturi tube should last at least 50- 100 years. During the meter modernization of the early 1990s, plastic insert venturi tubes were utilized at some 90 sites. Using this installation allows for cost effective replacement of these tubes in the future should a replacement become necessary. We continue to replace older venturi tubes, some as old as 100 years, with these newer insert venturis as pipeline and other major rehabilitation projects take place. If a new community comes on-line, staff will put together an in-house design and construction project to install a new meter.

The secondary equipment, noted above and pictured below, does require upgrade and replacement every 10-15 years. We are currently replacing older transmitters with a newer more accurate transmitter that will allow us to reduce/eliminate the use of low range transmitters in our system. Once completed, staff will be replacing the wired telemetry system with a wireless system. The last piece will be to replace all the data loggers within the next several years at an expected cost of approximately $750,000 – $1,000,000. The Master Plan costs include three cycles of replacement at $1,000,000 each during the FY19-53 time period.



A key theme for metering is the need for periodic replacement of the meters to ensure the most accurate information is being transmitted back to the Authority. The role of new technology is a critical element in how the meters are managed and when they are replaced. The Authority strives to stay on top of new metering technology and anticipate new technology changes.

Since the wastewater meters were just replaced, the next focus is on the replacement of water revenue meters and the associated Venturi tubes and meter enclosures. While electronic components are expected to last a minimum of ten years, Venturi tubes are expected to last at least fifty years. The tubes only become a problem when the inside becomes tuberculated, changing the calibration relationship. Significant meter rehabilitation work was +done at the largest community meters by the MDC in the mid-1980's but this work primarily involved the replacement of secondary equipment (new transmitters and steel chambers). In the early 1990's, MWRA replaced the remaining 90 or so smaller community meters and for these, the Venturi tubes were also replaced leaving approximately 53 meters that were pre-1992. However, a

number of Venturi tubes installed in 1903 remain in operation and the size and condition of these tubes is in question. Although 15 of the pre-1992 meters are included in other scheduled scopes of work, it may now be appropriate to initiate new contracts to replace the remaining meter equipment and Venturi tubes independent of other ongoing work. Replacing the remaining Venturi tubes will cost about $10 million. It would cost approximately $5 million to replace the water meters.

Recommended Projects-Metering

- Continuously review metering technology to stay abreast of changes to the technology.

- Proceed with meter and Venturi tube replacement already included within the scope of current pipeline and/or valve projects.

- Develop an asset protection program for water meter components for the duration of the planning period at an estimated cost of $15 million.

- Replace data loggers on an as needed basis through the FY19-53 planning period at a total estimated cost of $3 million.

Please refer to Chapter 12 of the 2013 Wastewater System Master Plan for a discussion of wastewater metering recommendations.

9.3 SCADA (Supervisory Control and Data Acquisition)

The SCADA system is a powerful process control technology used to monitor and control facilities and equipment locally and from a remote central location. It also provides a continuous record of facility operations. The SCADA system consists of four main components along with their software configurations and programs: 1) field instruments and equipment, 2) field programmable controllers, 3) communication devices and media, and 4) host computers. The Water SCADA System is maintained by MWRA staff.

The SCADA system has its genesis in the completion by staff in 1995 of a pilot project to automate the Reservoir Road Pumping Station. Now there are 61 water facilities on the SCADA system that are monitored and/or controlled. They include the Carroll Water Treatment Plant, the Ware Disinfection Facility, all the pump stations and their associate tanks, control valve chambers, reservoirs, and power generation facilities. The SCADA system makes extensive use of data radio and microwave radio communications to provide redundancy for critical signals and to provide long haul connections. The microwave system includes 8 high ground sites, such as MDC Hill in Southborough, that are not associated with water facilities but are used as relay points.

New water projects that will expand the SCADA system include UV disinfection at the Ware Disinfection Facility and the Carroll Water Treatment Plant, the new Spot Pond pumping station and covered storage, the continued rollout of water quality monitoring sites, the new Hultman control valves, the Lower Wachusett Gatehouse emergency disinfection and the Ware Fisheries hydro turbine. Some of these projects will be installed and programmed by MWRA staff and others by contractors.

Over time the SCADA system needs hardware and software upgrades. There has been a continual process of system upgrades and improvements through in-house and external projects using CIP and CEB funds. One recent example of this was an in-house upgrade of the Human Machine Interface (HMI) system including the computers, the operating system, the drivers and the HMI itself. A recent upgrade lead by a contractor was the work under a task order to upgrade the field programmable controller at the Gillis Pump Station. Another upgrade is a transition to a more flexible Verizon communications technology that when coupled with in-house network and microwave modifications will provide redundant communications for pump stations and critical valves to an enhanced backup Operations Control Center.

Recommended Projects-SCADA

- Evaluate the need for and timing of microwave radio replacement. This involves a mix of strategies including appropriate levels of spare parts, incremental upgrades, retirement of surplus routes, and larger contracted replacements. Examples of this approach include a recent staff installed microwave hop that replaced three other hops with older equipment that can now be retired, and a short term plan to replace the oldest microwave hardware at two western locations with CIP funds.

- Microwave towers should last approximately 75 years. The oldest towers in the SCADA system are on the Wastewater side and are scheduled to be replaced under the Headworks upgrade contracts. The Ward St tower is being retired and replaced with access to the top of the new Mass College of Art building. Continue to review and evaluate opportunities to replace towers or modify equipment locations as existing facilities age.

- Replace radio feed line and antennae by FY20 at a cost of approximately $1 million. Some of this work will be done incrementally.

- Replace radio equipment periodically on an as-needed basis. The Master Plan allocates $300,000 for this purpose in the FY15-53 time period.

- Replace or upgrade Waterworks PLCs every 15-20 years or when a significant enhancement in security architecture is released. Replacement or upgrade costs will depend on the level of reconfiguration and reprogramming required. For planning purposes, an equipment upgrade cost of $14 million during the FY20-53 timeframe has been assumed. Some of this work may be done incrementally by in-house staff.

- Replace communications and network equipment on an ongoing basis as needed over The planning period (FY14-53) at an estimated cost of $400K.

- Consider the use of cold-standby wireless communications for additional redundancy.

- Regularly review available communications technology and update and replace equipment as new features are determined to be beneficial to MWRA operations or as existing equipment becomes obsolete or where vendor support is no longer available.

- Constantly review our security stance and pursue required upgrades to achieve the designed protection.

Please refer to Chapter 12 of the 2013 Wastewater System Master Plan for a discussion of wastewater SCADA recommendations.

9.4 Laboratory Services

The Laboratory Services Section presented here is also presented in Chapter 13 of the Wastewater System Master Plan. All laboratory services costs programmed in the FY14 CIP and recommended for consideration in future CIPs are included only in the Water System Master Plan and not in the Wastewater System Master Plan so that there would be no double counting of overall costs.

MWRA's laboratory services are client based. Clients include Deer Island, ENQUAD, TRAC Drinking Water Programs (including MWRA communities) and the Department of Conservation and Recreation (DCR). To accommodate the range of program needs, the geographic range of the MWRA system, and the types of samples to be analyzed requires MWRA's Department of Laboratory Services to operate multiple laboratory facilities in Chelsea, Clinton, Quabbin, Southborough, and the Central Laboratory located on Deer Island.

Samples are generally taken by staff within various programs and submitted to the appropriate laboratory location for analyses in compliance with a range of regulatory requirements, though Laboratory Services collects regulatory samples at the Clinton and Deer Island Treatment Plants. For example, TRAC staff sample industrial discharges for permit compliance and Quality Assurance staff obtain samples from the Carroll Water Treatment Plant to ensure proper plant performance and compliance with federal and state drinking water regulations. To provide a sense of the magnitude of work, Laboratory Services analyzes more than 250,000 samples per year for MWRA programs and the 39 MWRA member water communities. The work for the communities allows MWRA to both ensure sampling consistency and to quickly recognize patterns of bacterial contamination that could potentially occur in the system. MWRA also analyzes all DCR's reservoir and tributary samples in accordance with the MOU between MWRA and DCR.

Given the magnitude of the work effort, Laboratory Services continues to be proactive in identifying current and emerging issues. Staff safety while handling and analyzing samples must be protected through training and use of well maintained laboratory equipment and facilities. Staff resources must be efficiently allocated to ongoing work while thinking ahead to potential regulatory changes that may occur, particularly the identification of emerging contaminants. The laboratory must work closely with other MWRA departments to try to anticipate which contaminants might actually become a problem in order to focus limited resources on the relevant contaminants. Key questions to be answered when considering which contaminants to gear up for include: (1) how probable is it that a particular contaminant will become a problem, (2) will the concern be short-lived or a long-term problem, and (3) how much training and equipment are involved? A second issue relative to staff resources is the need to staff laboratories seven days a week in order to accommodate various sampling needs and requirements. This is a particular issue at those laboratory sites with limited staff overall. Finally, data management tools must keep pace with both the laboratory work load and significant advances in technology. Projects identified for Laboratory Services address these challenges.

Facility needs generally include periodic reconfiguration of space for work efficiency or to adapt to new test and/or equipment requirements. This is of particular importance at the Central Laboratory where this issue is addressed jointly by Laboratory Services, Deer Island managers, Operations, and Finance. In addition, periodic replacement of analytical or safety equipment is necessary. Ventilation equipment is particularly critical in this regard. Fume hoods at the Central Laboratory are now recommended for replacement along with the rest of the HVAC system both to address worker safety and to preserve sensitive analytical equipment. The fume hoods in the metals preparation laboratory were replaced in FY12 because they had corroded due to acid used in metals tests. This is a recurring expense approximately every 15-20 years.

Data management was addressed in 2009-2010 through the replacement of the 17 year-old Laboratory Information Management System (LIMS). The benefits of a new LIMS are more automation, consolidation of data, and the ability to electronically report drinking water results to MassDEP. Any additional data management tools necessary to more fully utilize and interface with the updated LIMS system are identified and coordinated between MIS and laboratory staff.

Summary of Existing and Recommended Laboratory Services Projects

<u>Current Projects-Laboratory Services</u>

- <u>Fume Hoods and HVAC Systems</u> - In 2010, Laboratory Services and Deer Island Engineering staff concluded that the replacement of the Central Laboratory fume hoods and the Administration/Laboratory Building's HVAC system should be combined into the same design and construction contracts. DITP HVAC equipment replacement design, engineering services during construction, and construction to replace odor control and air handler equipment (including DITP laboratory fume hoods) is programmed in the FY14 CIP at a cost of $20.6 million during FY14-20. This project is carried as a DITP project in Chapter 6 of the Wastewater System Master Plan. This project is likely to present severe logistical issues for the Central Laboratory if large portions of the laboratory need to be shut down for extended periods of time. This may include the need for laboratory trailers that to meet MassDEP laboratory certification requirements. These contingencies will be addressed during the design contract.

- <u>Major Laboratory Instrumentation</u> **-** For decades the trend in environmental laboratory testing has been to detect lower and lower concentrations of contaminants in small quantities of complex samples. Over the past 20 years, decisions have been made as new contaminants have emerged into prominence whether MWRA should perform this testing in-house or contract the work out. These decisions have been weighted by whether the contaminant is likely to be important in MWRA drinking water or wastewater, how many samples are likely to need to be tested, and how expensive or complex the laboratory instruments will be. For example, when MassDEP began regulating perchlorate in drinking water, MWRA decided to contract out the few required samples a year since perchlorate was unlikely to be detected in MWRA drinking water. As MassDEP and

EPA continue to regulate more contaminants in drinking water and wastewater, it is likely that eventually MWRA will choose to purchase complex, and therefore expensive, laboratory instruments when the number or tests is likely to be large or the consequences of the testing critical to MWRA's mission. The CIP should continue to carry funding for major laboratory instrumentation, such as Dynamic Reaction Cell (DRC) ICP-MS (inductively coupled plasma mass spectrometry for metals and high resolution GC-MS (gas chromatography-mass spectrometry) or LC-MS (liquid chromatography-mass spectrometry) for organics. For these types of major laboratory instrumentation, $1.0 million is programmed in the FY14 CIP and spending is projected in FY15-18.

- <u>Laboratory Instrument Data Management</u> - Now that the LIMS upgrade has been completed, there is a need for ancillary in-house data management improvements for laboratory instruments. MassDEP certification and Massachusetts records retention laws requires that raw data from instruments be retained and accessible for up to 15 years. While the final results and a limited amount of raw data are transferred from the instruments' data systems to LIMS, the bulk of the raw data are retained and archived outside of LIMS. The current approach is labor-intensive, thus a more user-friendly, automated approach is needed. Laboratory Services has identified a need for this type of system and a $550,000 LIMS Enhancement Project began in FY13. As part of the overall IT Plan, programmed in the FY14 CIP is the remaining $545,000 with spending projected in FY15-18.

<u>Recommended Projects-Laboratory Services</u>

- <u>Laboratory Facilities Renovations</u> - Department of Laboratory Services staff, together with other MWRA Operations staff, should develop a system to efficiently and quickly reconfigure laboratory space to accommodate new sampling requirements or new equipment. This will allow the Laboratory to maintain high levels of efficiency with minimum disruptions to ongoing work. Laboratory Services staff should identify any technological changes or equipment that will assist in improving staff efficiency. The Central, Chelsea, and Southborough Laboratories are fairly new, while the Clinton and in particular Quabbin Laboratories are showing signs of age. A future project to facilitate renovations at all five laboratory facilities is recommended for consideration in future CIPs (planning, design, and construction) at an estimated total cost of $20.0 million over the 40-year planning period FY14-53 (this represents an average annual investment in the five laboratories of $500,000 per year).

- <u>Wireless LIMS and instrument interfaces</u> - Advances in wireless tablet and handheld devices will eventually become suitable for use in laboratories. Samples progress from the field to sample receiving, preparation, analysis, data processing, final reporting, and disposal. In the future, each staff in the laboratory is likely to have their own mobile device that is used for all tasks involving samples, instruments, and instrumentation which will increase productivity and reduce the need for paper records. A future project to purchase equipment and facilitate wireless laboratory transactions at all five laboratory facilities is recommended for consideration in future CIPs at an estimated total cost of $500,000 projected during the FY14-23 timeframe.

9.5 Information Management

In the 2006 Water and Wastewater System Master Plans, the focus relative to information management was on those areas particularly germane to the operation of a large regional utility. MWRA owns and operates many dozens of facilities, miles of tunnels, interceptors and pipelines, dams, treatment facilities and thousands of ancillary structures (manholes, valves, meters etc.). This results in an extensive number and range of documents and records to be maintained and continually updated. Tools for organizing and accessing this information are critical to allow information to be accessed both quickly in emergency situations and in an organized manner to facilitate long-term rehabilitation and replacement of MWRA assets and to design new system components. Information must also be available to document permit or regulatory compliance, protect MWRA assets from damage by outside contractors or utilities, and for responding to litigation, if necessary. Given decreased staffing levels, it is important that procedures and tools for information management be developed and used to facilitate access to the most accurate information in the most efficient manner. This includes the need to ensure that "baseline" information systems at MWRA are brought up to date and include all of the agency's current information and, equally important, that subsequent updates can be systematically added both to the baseline and to all of the other MWRA databases that rely on that baseline information.

In March 2012, MWRA completed a Five Year Information Technology Strategic Plan ("IT Plan"). This IT Plan was a result of conducting a base line analysis of IT best practices compared with actual MWRA IT operating conditions, identifying the future needs of the business and developing a target state for technologies, and developing a set of programs and plans to meet those needs. Program initiatives were identified within four areas: 1) Technology Infrastructure Program; 2) Application Improvement Program; 3) Information Security Program; and, 4) IT Management Program. From these four categories, 15 actionable programs were identified. For this water and wastewater master planning effort, the analysis of the current issues and recommendation are made within the context of the new MIS strategic planning efforts. As the plan notes on page 16 of 122: "*Data architecture defines a framework for the structure of an organization's logical and physical data assets and data management resources. The key objective is the ability to extract maximum business value from any data captured by the Authority, regardless of the data resource management system that contains it.*"

The actionable programs, from the four areas identified in the IT Plan, of greatest relevance to Water and Wastewater System Master Planning are those identified under Application Improvement Programs. But it should be noted that the Application Improvement Programs cannot and will not succeed if the programs within the other three program areas are not successfully completed. For the details associated with the interdependencies of each of the programs, see Appendix B of the IT Plan.

The initial recommendation from the IT Plan is that the Authority implement an Enterprise Content Management (ECM) program which would "address the organization's dependence upon paper records, support records management activities, improve access to information, streamline work flows, and replace several existing departmental-level solutions." According to the IT Plan, ECM is an umbrella term which among other things includes document management, records management and work-flow management activities. These endeavors are particularly relevant to the issues discussed in the 2006 Master Plans including Record Drawing Management, Mapping and Modeling Issues and Work Order Management using Maximo.

As a note, the project costs associated with implementation of the recommendations of the IT Plan are not included in Table 9-1. Appendices C and D of the IT Plan address costs and schedule. The FY14 CIP also incorporates the plan recommendations.

Record Drawing Management

Record drawings are the major category of information maintained by MWRA and these also provide the basis for MWRA's GIS-based mapping and modeling systems. Authority record drawings exist on hardcopy and film, and are located in the Records Center, as well as at a number of MWRA and DCR facilities. A survey of these locations estimates the total number of drawings referencing MWRA infrastructure at 75,000. A subset of 60,000 of those drawings has been electronically scanned to the network. Record drawings at these locations vary from complete sets on recent contracts, to incomplete sets on pre-MWRA contracts, and partial sets for others. Design Information Systems Center (DISC) staff from the Engineering Department are involved in a review of these drawings in order to secure the latest revision for MWRA use. Drawings secured by DISC are chronicled in a number of pre-MWRA logbooks, recent departmental databases, and/or the Authority-wide document control system.

Organized drawing collections include the Records Center drawing archive, Chelsea water and sewerage microfilm archive, Deer Island (the Technical Information Center–TIC), the Western Operations files, Metro Operations files, and the Wastewater Engineering Unit compilation of recent construction projects, along with other miscellaneous collections. When a request for record drawings is made by staff or by outside consultants or contractors, staff search these sources first. InfoStar, acquired through the Boston Harbor Project, is used as the indexing tool. InfoStar requires replacement since the product is obsolete and there is no vendor support. Newer technology would provide improved efficiency and management control. Extensive documentation of current practices and procedures for processing record drawings, shop drawings, specifications, field sketches, etc. must be completed to ensure that any new system will thoroughly meet Authority needs.

In addition to proper management of records previously developed, there remains concern about missing or inaccurate records and the continued maintenance of multiple databases. As ECM programs are put in place, it will be critical to simultaneously begin to determine what records are missing or inadequate and institute projects to obtain the best available information. As an example, a preliminary review of GIS information indicates that relative to the water system records, approximately 120 record drawings and approximately 250 detail records are missing, incomplete or require updating. In addition, as an ECM approach is developed, historical issues such as non-standardized nomenclatures or lower/upper case differences, different data formats (Access v. Excel as an example) and variability in data collected for projects should be addressed. Mechanisms to efficiently update information so that the updated information is simultaneously available to all users should also be addressed. A broad based group of Authority staff familiar with the Authority's business practices and with both the current uses of these sources of information should be convened by MIS staff to ensure that these issues are addressed. Consultant assistance may be required to assist in the development of missing information.

Current Projects-Records Management

- The Document Control System Software Replacement project (previously in the CIP at a $2 million value), has been folded into the Enterprise Content Management CIP project for consistency with the IT Plan. Work is expected to start in FY14.

- The Distribution Systems Facility Mapping Records Development project is currently in the CIP and work is projected to start in FY16. This project is designed to develop or update record drawings and detail records for critical areas within the water distribution system where accurate records do not currently exist. The budgeted cost is approximately $763,000.

Mapping and Modeling

MWRA sewer and water infrastructure data is created from Record Drawings and Detail Records and stored in GIS. GIS is then used to update the hydraulic model. A change in the field brought about by a capital improvement or an in-house project causes a chain reaction of updates: record drawings and detail records need to be updated and finalized, then submitted to GIS so the GIS and hydraulic model can be updated. An up-to-date GIS and hydraulic model facilitate flow of accurate information during emergencies, future project planning, and even master planning efforts. Thus, many of the recommendations for ensuring updated mapping and modeling data are the same as for ensuring that accurate record drawing information is available.

Again, program initiatives under the IT Plan's Application Improvement Program address GIS Applications and Integration. GIS use at the Authority has increased exponentially over the years for water and wastewater site and routing studies, environmental analyses, hazard mitigation analyses, real property applications and litigation, and many other scientific, environmental and engineering uses. It also has the potential to "spatially enable" other Authority applications including programs such as sewer inspections, PIMS, expanded Maximo functionality and others. The IT Plan recommends that an agency-wide GIS strategic plan be developed which would identify organizational roles and responsibilities, project priorities and processes for updating the GIS and keeping the data current. As developed in the IT Plan, the FY14 CIP provides a cost estimate of $350,000 for this purpose with the work expected to take place in the FY14-18 time period.

Although it is not solely related to mapping and modeling, the IT Plan also identifies Mobile Integrations as another initiative. The relationship to MWRA's GIS system and to mapping and modeling efforts is that immediate data entry at the source will help to update system information in the most timely fashion so that subsequent use of that information is accurate. In addition, it can be noted when previously mapped information is determined in the field to be inaccurate. Even applications as simple as noting and GPS locating pipe breaks or leaks, would allow that information to be accessed more efficiently than thru handwritten notes and map points. The GIS strategic plan proposed above should consider possible standard applications and procedures for mobile integration. This relates to the suggestion under Record Management as well, that the broader user group should discuss and address the issue of multiple versions of some databases. Mobile integration programs should work in conjunction with an identified primary database. The estimated cost of the Mobile Integration program as recommended in the IT Plan is $150,000 and this has been incorporated into the FY14 CIP with implementation in the FY14-17 time period.

Work Order Management-Maximo

Maximo is currently used as a work order maintenance system and it is designed to provide the planning function for the Maintenance Group. The Work Coordination staff use MAXIMO for planning and scheduling work and reporting on labor utilizations hours and percentage of work orders completed. MWRA staff also use MAXIMO to manage asset repair costs and to evaluate that cost in the determination of further equipment repair or replacement. The data are also used for specialized analyses.

Use of Maximo is always being reviewed and refined. The IT Plan recommends the completion of the migration to Maximo Version 7.5, acquisition of additional modules and richer integrations, reconfiguration, improvements to work flow and reporting and business process improvements to exploit the added functionality. Currently, MWRA uses Version 5.2 which is not compatible with Windows 7. MIS has developed integrations that use Lawson materials data to cost work orders and enables purchase requisitions to be linked to specific work orders. MIS has also developed a “one-way” integration between underground assets and GIS spatial data. Users can click on the representation of an asset on a GIS map and view Maximo asset attributes and work order history. Additional specialized applications have been developed to store maintenance management data including Lube sampling database; Preventive Maintenance Monthly Report; Predictive Maintenance Monthly Report; Reliability Centered Maintenance; Resource Leveling. And, Tool Tracking. The upgrade to Version 7.5 will eliminate the need for some of these in-house developed applications. That will mean that users will have a more fully integrated solution, redundant entries will be eliminated and MIS support needs should also be reduced. The added functionality of the updated version will also allow for future integrations, particularly with GIS. Migration to the updated version has begun. Maximo upgrades are in the FY14 CIP at a cost of $1.75 million with work scheduled for FY14-18.

Pretreatment Information Management System

Another application improvement program identified in the IT Plan with relevance to wastewater operations is the proposed enhancement to the existing Pretreatment Management System (PIMS). This package is used by TRAC to monitor industrial pretreatment permits, inspections, sampling, and enforcement activities for MWRA’s 210 Significant Industrial Users and 1,400 permitted facilities. PIMS integrates with MWRA’s Laboratory Information Management System which provides the results of samples. According to the IT Plan, this enhancement program will assess the current state of PIMS implementation with the intent of developing a plan to address both existing functional issues and also to comply with new regulatory requirements. This effort is estimated to cost approximately $400,000 and this cost has been incorporated into the FY14 CIP with work in the FY14-17 time period.

Conclusions

The assessment work that was done in preparation of the IT Plan identified and further examined issues raised in the 2006 Water and Wastewater System Master Plans. Providing an Enterprise Content Management (ECM) framework for data will be a critical first step. For GIS-related efforts, the need to convene a broad-based group within the Authority to address the issues identified by users; to ensure that data standards are developed; and, that the integration of GIS with other existing and future Authority applications is of critical importance. As these efforts move forward, it will also be critical to identify and address issues with missing and/or inaccurate data. Increased confidence in data accuracy and improved accessibility along with the increased functionality of various applications should result in increased efficiency and improved response time for both day to day and emergency scenarios.

The above section on Information Management is also presented in Chapter 13 of the 2013 Wastewater System Master Plan. In addition, further detail is included in MWRA's IT Plan, March 2012. Costs for the MIS work discussed above are contained in the Strategic Plan and have been incorporated into the FY14 CIP.

9.6 Security

The Security section presented here is also presented in Chapter 13 of the Wastewater System Master Plan. All security costs programmed in the FY14 CIP are included only in the Water System Master Plan so that there would be no double counting of overall costs.

MWRA's investment in security for water and wastewater pipelines and facilities, as well as, the Authority's information systems, has increased significantly over the past twelve years. Since 2001, MWRA has invested approximately $7.5 million in security related upgrades specific to security equipment and installation projects. Additional funds have also been expended that were included within individual capital projects for new or rehabilitated facilities. A detailed description of MWRA security measures is not included in the Master Plan due to the sensitive nature of the topic. In general, MWRA has been evaluating and ranking facilities and locations with respect to the critical nature of service delivery for each site. As appropriate, effective security improvements are planned, scheduled, and constructed. In general, MWRA's security improvements include:

- Gate and signage upgrades to limit access in specific areas and to denote areas where the public is welcome;
- Access card readers at facilities to monitor entry;
- Locked/unlocked door alarms monitored continuously;
- Video camera monitoring of key locations;
- Central monitoring of data and alarms for all facilities;
- Automated water quality monitoring;

- Planning and coordination with state and local police;
- Planning and drills for incident response;

Current Projects-Security

- Additional expenditures under the Security Equipment and Installation project are included in the FY14 CIP at $1.295 million during FY14-15. This project will continue to upgrade security measures for water and wastewater facilities.

- Information systems security is an integral part of the MIS Strategic Plan. A number of MIS security related projects are combined under the Information Systems Program and are budgeted in the FY14 CIP at $792,000 and scheduled during FY14-17.

Recommended Projects-Security

- It is anticipated that security technology/electronic components will need to be replaced or upgraded periodically due to obsolescence, vendor support or wear. The Master Plan includes $3,500,000 in the FY19-53 time frame to be used as needed.

Table 9-1

Water Master Plan - Laboratory Services, SCADA, Metering, Information Management and Security

Existing and Recommended Projects

Last revision 9/18/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF New Facility/System
RF/IC Replacement Facility/Increase Capacity
Opti Optimization
AP Asset Protection
Plan Planning/Study

FY14 CIP Notes

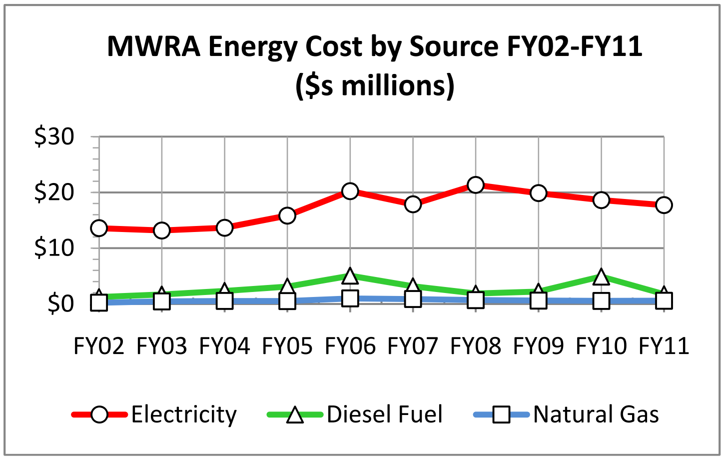
Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
9.01	3	Major Lab Instrumentation	Opti	881	98457_7309	4 years	1,000	FY15-18	1,000				1,000
9.02	2	Meter Vault Manhole Retrofits	AP	766	75490-6689	4 years	1,929	FY16-19	1,757	172			1,929
9.03	3	Water Meter Upgrade & Replacement	AP/Opti	766	75536_7453	2 years	1,000	FY16-17	1,000				1,000
9.04	3	Records Development	AP	763	75484_6525	3 years	763	FY16-18	763				763
9.05	2	Security Equipment and Installation	New/Opti	881	92374_6760	2 years	1,295	ongoing-FY15	1,295				1,295
9.06	2	Winsor Dam High Line Replacement	AP	753	75512_7338	1 year	1,000	FY14	1,000				1,000
		SUBTOTAL - Existing - Lab, SCADA, Metering, Info Mgmt and Security					**6,987**		**6,815**	**172**	**0**	**0**	**6,987**
9.07	3	Laboratory Renovations	AP/Opti	New		ongoing	20,000	FY14-53	2,500	2,500	5,000	10,000	20,000
9.08	3	Wireless Laboratory Transactions	Opti	New		10 Year	500	FY14-23	250	250			500
9.09	2	SCADA Radio Feed Line and Antennas	AP	new		5 Years	1,000	FY19-23		1,000			1,000
9.10	3	Radio Equipment-As needed	AP	new		as needed	300	FY15-53	70	30	100	100	300
9.11	3	Waterworks PLCs-as needed	AP	new		as needed	14,000	FY20-53		3,000	4,000	7,000	14,000
9.12	3	Networking Communications Equipment	AP	new		as needed	400	FY14-53	50	50	100	200	400
9.13	3	Water Meter Asset Protection-ongoing	AP	new		as needed	15,000	FY14-53	2,500	2,500	5,000	5,000	15,000
9.14	2	Data Loggers-as needed	AP	new		as needed	3,000	FY19-53		1,000	1,000	1,000	3,000
9.15	2	Security Equipment Replacement/New Technology	AP/Opti	new		as needed	3,500	FY19-53		500	1,000	2,000	3,500
		SUBTOTAL - Recommended - Lab, SCADA, Metering, Info Mgmt and Security					**57,700**		**5,370**	**10,830**	**16,200**	**25,300**	**57,700**
		SUBTOTAL - Existing and Recommended - Lab, SCADA, Metering, Info Mgmt and Security					**64,687**		**12,185**	**11,002**	**16,200**	**25,300**	**64,687**

10 Energy Management

10.1 Chapter Context and Summary

MWRA's costs for electricity, diesel fuel and natural gas are a significant portion of direct expenses. MWRA's total energy demand (for both the water and wastewater systems) of 210,800,000 kWh and 493,250 therms (electricity and natural gas only) is equivalent to about 18,500 homes. Energy costs ranged from $15 million (8.4% of total direct expenses) in FY02 to $20 million (9.9% of budget) in FY11 (due in part to the addition of major new facilities including the Carroll Water Treatment Plant and to the varying price of energy). Spending temporarily escalated to $26 million (13.8% of directs) in FY06 from the spike in energy costs subsequent to Hurricane Katrina. This event highlighted the volatility of energy prices and reinforced MWRA's efforts to aggressively manage energy usage and costs as an important part of MWRA's overall rates management strategy.



Notes:

- Significant increases in diesel fuel and electricity prices in FY06 to FY07 due to Hurricane Katrina.
- Significant increases in electricity prices again in FY08-FY10 due to market. Offset by declining purchases due to self-generation and energy-efficiency projects.
- Diesel fuel purchases increased in FY10 due to extensive CTG use during spring storms.

MWRA's energy initiatives have focused on all energy utilities but the major emphasis has been on reducing costs for electricity since it accounts for over 80% of the energy spending.

Strategies are generally broken into demand-side strategies and supply-side strategies. Demand-side strategies focus on opportunities to implement additional energy conservation measures as well as to maximize the use of existing and potential new base-load self-generation assets to reduce or offset MWRA's need for purchased energy. Supply-side strategies include efforts to focus on reducing energy costs through the optimization of competitive energy supply contracts while maintaining a balance energy portfolio. Other supply-side initiatives include continued evaluation of the operational and economic feasibility of enrolling back-up generation assets in load reduction programs and evaluating opportunities to shave peak demand thereby reducing electricity demand charges.

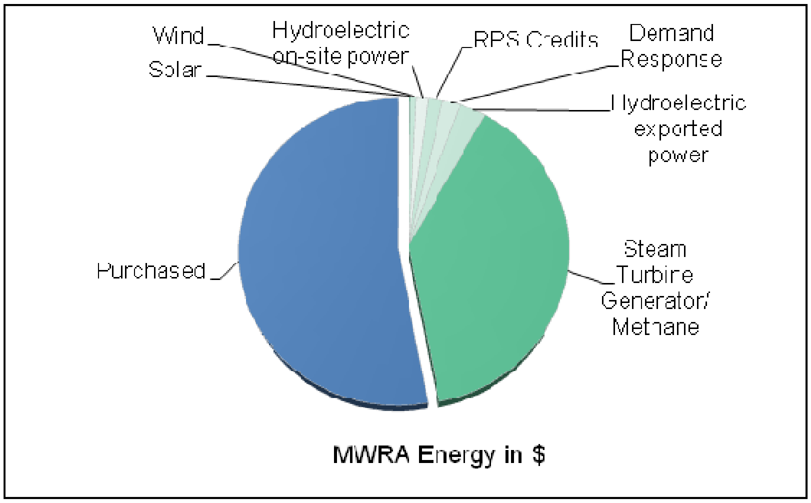
In 2007 Governor Patrick issued *Executive Order 484-Leading By Example-Clean Energy and Efficient Buildings* which directed, among other things, that state agencies make strides in energy conservation, reduction of greenhouse gases and development and use of power from renewable sources. Progress was to be tracked and specific targets were set. In this same time frame, additional opportunities for state and federal energy related grants became available including the 2009 American Recovery and Reinvestment Act which prioritized a portion of funding for renewable energy projects. Utility rebates for energy efficiency have also continued to be an important component in an overall energy management strategy. Extensive progress has been made since FY02 and the following bullets highlights reflect the breadth of MWRA's work:

- The total CEB impact of these energy savings and revenue initiatives has been approximately $170 million during the FY02 to FY11 period with annual savings and revenue of $24 million in FY11.
- Annual energy savings and revenues have increased from about $6 million to almost $24 million over the past decade (which reflects the addition of new energy generating equipment and facilities, additional revenues, and reduced energy use).
- Almost half of MWRA's total energy cost profile is derived from renewable sources (demand response, STG/methane, wind, hydro, solar, RPS credits).
- MWRA has completed energy audits at its major facilities. Implementation of audit recommendations and other process optimization efforts is estimated to save almost $2 million annually.
- As a result of aggressively pursuing opportunities for grants and rebates, MWRA was awarded over $12 million for funding of renewable energy and energy efficiency related projects (wind, solar, hydro).
- From 2005 to 2011, MWRA has received eight regional and national awards (most recently a 2011 Massachusetts State Leading by Example Award) for energy program leadership and project completion.

The sections below discuss MWRA's work to implement renewable energy projects, demand-side management programs, supply-side management programs, green power programs and recommendations for future work.

10.2 Renewable Energy

Consistent with Executive Order 484 issued by Governor Patrick in 2007, MWRA has made a priority of siting new renewable energy projects at as many facilities as economically feasible and continues to aggressively seek out any available grant and loan funds to improve project paybacks. Each renewable project is reviewed on a case by case basis to evaluate the reasonableness of payback periods (including the impact of grants and rebates). As shown below, almost half of MWRA's total energy cost profile is derived from renewable sources.



MWRA's renewable energy generation of 58,320,000 kWh (not including the thermal value of digester gas) is equivalent to about 5,000 homes. This is similar to MWRA service area towns the size of Wilmington, Ashland, Bedford, and Swampscott.

Wind – MWRA has four operating wind turbines: two 600kW turbines at DITP, one 100kW prototype FloDesign turbine at DITP and one 1.5 MW turbine at Charlestown Pump Station. These turbines are expected to generate over 5 million kWh per year and provide a projected annual savings in electrical costs and revenue of about $580,000. Potential future Deer Island wind projects are discussed on page 10-9.

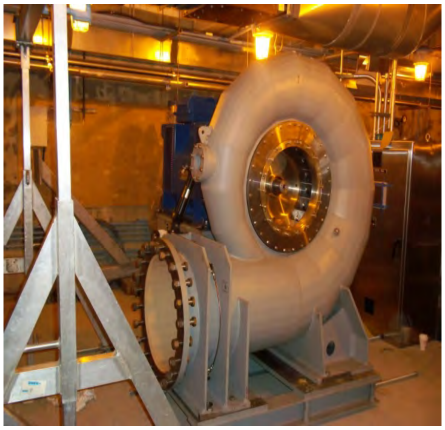
1.5 MW Turbine in Charlestown

476 kW photovoltaic system at Carroll

Solar – Solar photovoltaic systems are currently installed at Deer Island on the roofs of the Residuals/Odor Control, Maintenance/Warehouse and Grit Buildings and on the ground in the south parking lot. A system is also located on the grounds at the Carroll Water Treatment Plant.

The systems represent over 1.2 MW of capacity and will produce over 1.4 million kWh per year of electricity and provide projected annual electrical cost savings and revenue of approximately $240,000.

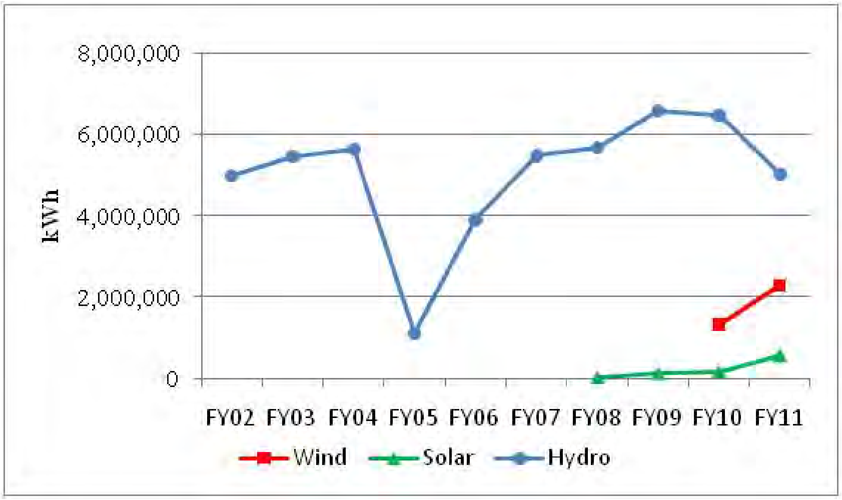
Hydroelectric - MWRA has a long history of using hydroelectric energy and continues to look for opportunities to capture the potential energy of water as it moves from higher to lower elevations. Hydroelectric facilities are currently located at Deer Island, Loring Road, Oakdale and Cosgrove. These facilities represent over 8 MW of capacity and will produce about 23 million kWh of electricity per year with projected annual savings and revenues of over $1,800,000.



Hydro Turbine at Loring Road

Hydro Turbine at Oakdale

The graph below indicates the increasing production of solar power at MWRA (beginning in FY08) and wind power (beginning in FY10). This will continue to increase as new solar and wind facilities are added (including the Charlestown turbine and Carroll solar which started in FY12). The hydropower generation fluctuates year to year based on water transfer needs and was particularly low in FY05 and 06 during start-up of the CWTP (as the Cosgrove generator was offline) and due to major maintenance of the Deer Island hydro turbine.



Methane - The capture of methane from the digesters was included in the original design contract of the Deer Island Treatment Plant. Co-generation at the Deer Island Thermal Power Plant (capacity of over 6 MW) using methane saves MWRA approximately 5 million gallons per year in annual fuel oil purchases (to heat the digesters and Deer Island buildings). The Power Plant Steam Turbine Generator at Deer Island allows MWRA to use steam from the methane powered boilers to produce electricity (valued at about $2.3 million in FY11). Ongoing optimization upgrades at the thermal power plant/steam turbine generator are expected to result in a total additional annual electrical savings and revenue of about $700,000. In addition, methane is a potent green house gas; therefore, its capture and use significantly reduces MWRA's carbon footprint.

Massachusetts Renewable Energy Portfolio Standard (RPS) – Retail electricity suppliers are required by Massachusetts regulation to provide a portion of their power from renewable energy sources. Renewable energy generators (like MWRA) can sell credits to electricity suppliers to help them meet the regulatory requirements. Since December 2002, MWRA has been selling its renewable energy credits through a competitive bid process. MWRA RPS eligible facilities have increased in recent years due to both new facilities being brought on line, as well as the Green Communities Act regulations that made hydropower eligible in 2009. MWRA has received about $8 million in RPS revenue to date.

Regional Greenhouse Gas Initiative (RGGI) - Ten Northeast and Mid-Atlantic States participating in the Regional Greenhouse Gas Initiative have designed and initiated the first market-based, mandatory cap and trade program in the United States to reduce greenhouse gas emissions. The states sell emission allowances through auctions and invest proceeds in consumer benefits: energy efficiency, renewable energy, and other clean energy technologies. The Deer Island combustion turbine generators (CTGs) are subject to the Massachusetts CO_2 Budget Trading Program, which implements the RGGI program in Massachusetts. MWRA must hold CO_2 allowances equal to CTG CO_2 emissions as of the end of each three year control period, the first of which ended December 31, 2011. As of March 2013, MWRA has purchased 54,000 CO_2 allowances (tons) at a cost of $123,230.

10.3 Demand-Side Management

MWRA demand-side management efforts include:

- Improving equipment energy efficiencies at operating facilities (lighting, variable frequency drives, HVAC system updates, treatment process modifications, etc.);
- Establishing operating protocols to reduce monthly and annual peak energy demand charges; and,
- Enrolling in demand response programs offered by regional grid operators.

Facility Energy Audits

Water and wastewater utilities are large energy users. The Governor's EO 484 and Mass DEP and EPA efforts have focused on demand-side management in wastewater and water facilities. MWRA has put significant effort into energy conservation through implementation of energy audits at 28 of it 36 major facilities, process optimization, and installation of energy efficient lighting and equipment, saving about 8 million kWh and $1,700,000 in FY 11. Energy audits of the eight remaining major water and wastewater facilities were conducted during FY 12 and recommended projects are being evaluated and implemented.

The addition of ventilation setbacks at Chelsea Creek Screen House, Columbus Park Headworks, and Ward Street Headworks are another example of the type of facility project implemented.. The total expected annual savings from these three projects is 467,400 kWh, 39,000 gallons of fuel oil, 6300 therms, and $179,000. These projects were 100% funded through NSTAR and ARRA, resulting in no cost to MWRA implement. VFDs were also installed on chemical scrubber pumps at Columbus Park and Ward Street Headworks. The total expected annual savings from these two projects is 242,000 kWh and $34,000. Both of these projects were funded through NSTAR and ARRA, resulting in no cost to MWRA to implement. Enroll the three headworks facilities in the demand response program.

Engineering design reviews are undertaken by staff on all in-house projects for facility energy optimization (such as the proper selection of pumps, motors, lighting, etc.) to ensure that they are premium efficiency and eligible for utility rebates.

Demand Response Programs

The Carroll Water Treatment Plant and Deer Island participate in a demand response program run by ISO-New England that pays these facilities a monthly “capacity fee” for being available to go on back-up generation during periods of extremely high New England grid electricity demands. Deer Island began participating in 2001 and Carroll in 2008. The total revenue received under this program through FY11 was $6.8 million. Additional facilities continue to be evaluated for enrollment in this program and Chelsea Creek, Columbus Park, and Ward Street Headworks are enrolled in the Demand Response Program as of April 1, 2012. The total annual expected revenue from enrollment in this program for these three facilities is $26,000.

Deer Island and Carroll have also avoided “peak capacity” charges by going off the grid during the ISO-NE peak operating hour. Monthly facility demand charges for the calendar year are set based on this peak hourly load. The total annual FY10 and FY11savings by these two facilities by avoiding this charge ranges from about $800,000 to $1,000,000. Staff also modify facility pumping operations and testing.

10.4 Supply-Side Management

Due to its large power purchasing, MWRA was an early entrant to the competitive electricity marketplace in 2001. The process has evolved into the creation of three distinct electricity supply contracts:

- Deer Island;
- The larger operations facilities including the Carroll Water Treatment Plant, Nut Island Headworks, Clinton Treatment Plant, and 22 other facilities; and
- The smaller accounts (e.g. CSO facilities, some pump stations).

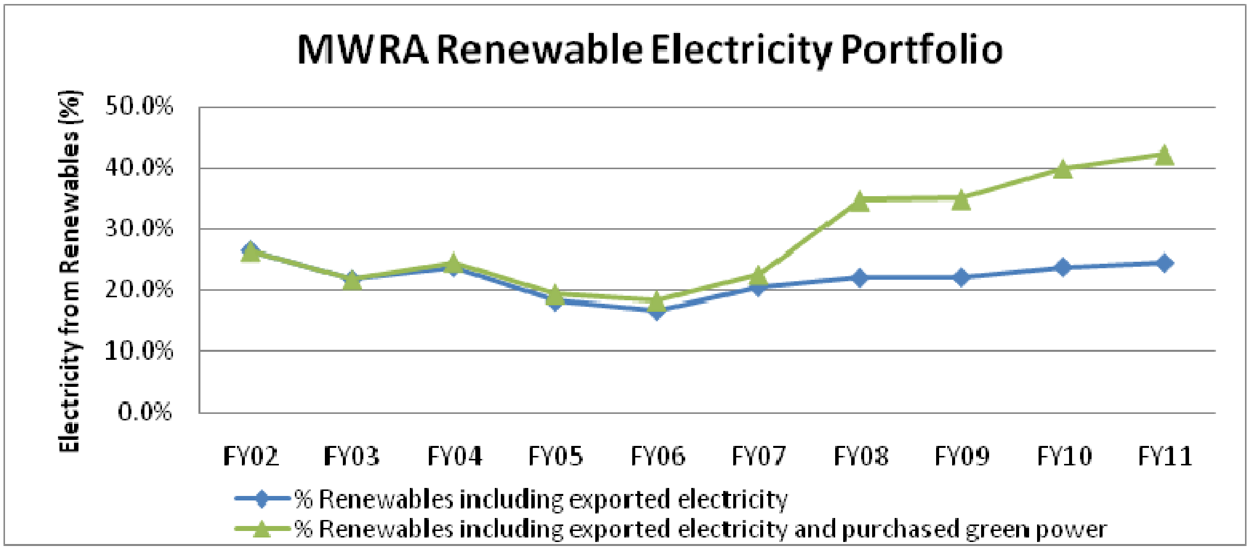
MWRA maintains a balanced electricity portfolio by contracting for a base block of power at a fixed-price and purchasing the balance of the load on the open market at real-time clearing prices. Currently over 60% of MWRA power is purchased on the fixed market. Estimated savings over the last 10 years from MWRA purchasing power competitively versus buying directly from the utilities are about $30 million. MWRA's largest electric accounts are shown in Table 10-1 below.

Table 10-1
Largest MWRA Electric Accounts

Facility	**Annual Purchased Electricity (kWh)**	**Percent Share**
Deer Island Treatment Plant	116,486,400	68.5%
Carroll Water Treatment Plant	10,387,608	6.1%
Nut Island Headworks	6,606,600	3.9%
Chelsea Maintenance Facility	2,672,200	1.6%
Newton St. Water Pump Station	1,239,600	0.7%
Braintree/Weymouth Intermediate Wastewater Pump Station	1,769,600	1.0%
Spring St. Water Pump Station	2,109,600	1.2%
Clinton Treatment Plant	2,133,697	1.3%
Subtotal	*163,659,000*	*84.3%*
Other Facilities	26,755,257	15.7%
Total	**170,160,562**	**100.0%**

10.5 Green Power and Other Sustainability Initiatives

In addition to all the efforts discussed above in support of MWRA and Commonwealth shared goals to increase renewable energy purchases and reduce greenhouse gas emissions at state facilities, MWRA has undertaken additional efforts to directly use more green power by maximizing the use of alternative fuel vehicles (biodiesel, CNG, hybrid, propane, and flex-fuel) representing about 70% of the fleet, and procuring green power ("National Green-e power") as a portion of our total electrical purchases. The figure below shows how the percentage of our total electrical power use that is produced or purchased from green sources has increased over time.



10.6 Summary of Existing and Recommended Initiatives

Hydropower – The FY14 CIP includes two hydropower projects. In the FY16-17 time period, approximately $1,446 million is included for a Wachusett hydropower project. However, at this time, it appears that permitting and the need to carefully assess any changes in releases to the Nashua River, may impact the potential development of this project. However, staff plans to explore alternative locations in the water transmission system which may provide hydropower development potential. Another hydropower installation is associated with the development of the fish hatchery pipeline at Quabbin Reservoir at an estimated cost of $670,000. The pipeline will convey cold, fresh water from the CVA to the downstream hatchery. The hydropower facility would be part of this project with power for use at the Ware Disinfection facility and sold to the grid. The project is scheduled for FY15-16.

Solar - Staff are working with a solar energy consultant to conduct a comprehensive solar feasibility study for all MWRA sites, to assess the solar capability, and technical and economical feasibility. Detailed feasibility studies have recently been completed for the 14 top-ranked sites from the desktop survey assessment. These studies will provide MWRA with better quantification of its solar assets and valuable information to help identify a procurement process to lead to additional renewable energy infrastructure installations. Any installations resulting from this project would likely be developed as third party power purchase agreements and would therefore not require CIP funding.

Wind – There are currently two future wind development projects in the CIP. The Deer Island Wind-Phase 2 project is expected to be developed by the City of Boston under an 8M permit issued by MWRA. This site has received FAA approval and is where the former Construction Support Building had been located. The second project, Future Deer Island Wind Construction would be located at the Secondary Battery D site where an MET tower is currently collecting wind data. Two turbines could be located at this site. FAA approval has not been sought for this location. The project is currently scheduled for FY16-21 at an approximate cost of $4,615 million.

Demand-Side Management

The following projects are recommended and several are already ongoing and expected to be completed in the short-term.

- Install an energy management system (EMS) at the Chelsea Facility to automatically control all HVAC equipment optimizing heating and cooling energy use. This project will save approximately 600,000 kWh and 7000 therms annually for an annual cost savings of $106,000. The total project costs after the applicable NSTAR rebate is $276,000. A similar project is planned for the Southborough facility.

- Energy efficient lighting upgrades at Columbus Park and Ward Street Headworks. These lighting upgrades will be done in two phases; the first phase will replace the current high pressure sodium lights in the screens area with explosion proof energy efficient induction lighting, and the second phase will replace the lighting in the rest of the building.

- Consider expanding the use of SCADA from process control to include more energy management functions.

- Continue lighting improvements at DITP. Phases 1, 2, 4 and 4A completed. Phase 3 includes outdoor lighting and lighting controls to be integrated throughout the plant.

- Replacement of more energy efficient motors and VFD’s at SMPS and NMPS. SMPS is complete and NMPS work expected to begin FY13.

- Process optimization efforts continue in the DITP cryogenics facility and secondary reactor process. These efforts include decrease in the oxygen feed and production to result in significant electricity savings projections. Pilot testing phase ongoing.

None of the projects identified above would require any MWRA capital funds.

Table 10-2

Water Master Plan-Energy Management

Last revision 9/17/13

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY14 CIP Notes

Excludes permit, legal easement and technical assistance costs
new project, not previously in CIP

Line No	Priority	Project	Project Type	FY14 CIP Project No.	FY14 CIP Contract No.	Project Duration	Cost ($1000)	Schedule	FY14-18	FY19-23	FY24-33	FY34-53	Total Cost ($1000)
									5 years	5 years	10 years	20 years	
10.01	4	Deer Island Wind Phase 2-Construction	NF	935	98463_7321	2 years	2,463	FY16-17	2,463				2,463
10.02	4	Future Deer Island Wind Construction	NF	935	92430_7270	3 years	4,615	FY18-20	963	3,652			4,615
10.03	4	Wachusett Hydro Design & Construction	NF	935	98448_7300	2 years	1,446	FY16-17	1,446				1,446
10.04	4	Fish Hatchery Pipeline Hydro	NF	935	98465_7323	2 years	670	FY15-16	670				670
		SUBTOTAL - Existing - Energy Management					**9,194**		**5,542**	**3,652**	**0**	**0**	**9,194**